A Healthy Coral Reef in the Southeast Asia Sea

The Planetary Coral Reef Foundation

Overview

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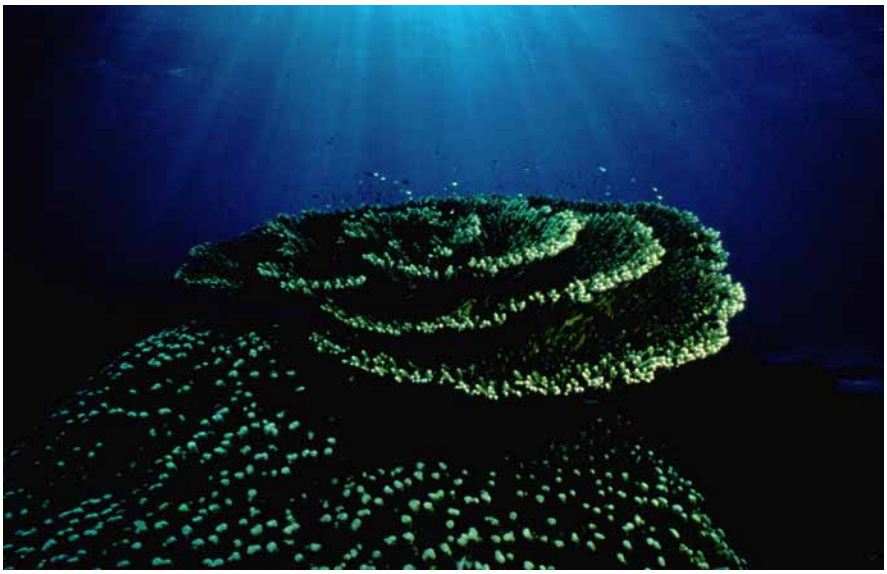
Our Vision



To stop the destruction

of the world's coral reefs by 2020

and restore their beauty,

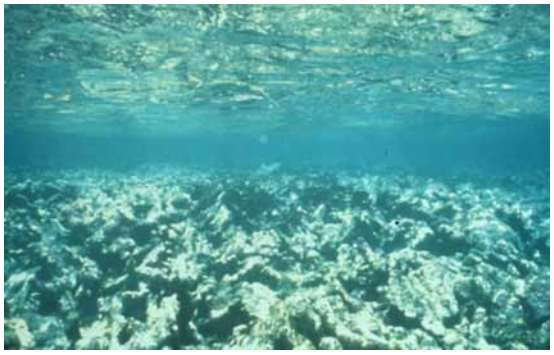
health and abundance

within this century.

The Coral Reef Crisis

Coral reefs are the most biodiverse of all marine ecosystems and the greatest expression of ocean life. Also known as the "rainforests of the sea," they are the barometer for the health of our oceans and possibly our entire global environment. Coral reefs are now in crisis – dying at an alarming rate worldwide. Threatened by pollution, over-fishing, dynamiting and bleaching, coral reefs are now endangered on a planetary scale.

Florida's Carysfort Reef, Healthy Condition 1975



Florida's Carysfort Reef, Now Dead 1999

About the Planetary Coral Reef Foundation

The Planetary Coral Reef Foundation (PCRF), a 501(c)(3) organization, was founded in 1991 to address the coral reef crisis. Since its inception, PCRF has pursued an unprecedented approach to the crisis, launching an innovative scientific and educational campaign worldwide. Crewed by an entirely volunteer team of officers, scientists and students, PCRF's research vessel, the *RV Heraclitus*, is now completing its eighth year of an ongoing expedition dedicated to mapping, monitoring and preserving the world's coral reefs.

As no comprehensive baseline map of living coral reefs has been charted, PCRF is working to accomplish this critical goal by pioneering new technologies including the launch of a special space-based coral reef sensor in cooperation with scientists at the College of Charleston, MIT, Scripps Institution of Oceanography, the Stevens Institute of Technology and USC.

***Between 1996 and 2000, the Florida Keys suffered an estimated 38% loss of coral reefs.**

I. The Coral Reef Crisis

Coral reefs around the world are dying. Lining 60,000 miles of shoreline along 109 countries, reefs and their related fisheries, marshlands and lagoons are vanishing. Home to more than a quarter of all fish species on Earth, an estimated 10% of coral reefs have already disappeared and an estimated 58% of all coral reefs are at risk today. In Southeast Asia, more than 80% of the reefs are at risk and an estimated 38% of the reefs in the Florida Keys died between 1996 and 2000. Threatened by pollution, over-fishing, dynamite and cyanide fishing, as well as bleaching most likely caused by rising ocean temperatures, coral reefs are now endangered on a planetary scale.*****

Coral reefs are the most productive, biodiverse, and sensitive marine ecosystem. Called the "rainforests of the sea," coral reefs are a complete community of algae, plants, animals and microscopic organisms comparable to the colorful variety and complexity of life in a tropical rainforest on land. Coral reefs and their habitats play a vital role in the global economy, providing resources and services worth an estimated $375 billion per year including: shoreline protection from erosion, fish nursery habitats, pharmaceuticals, tourism, and food for an estimated 10% of the world's population.*****

Coral reefs are also an integral part of the earth system biogeochemical processes, including primary production, carbon and calcium storage, and geological formations that facilitate water flow and upwelling. Research has demonstrated that coral reefs respond more quickly than any other ecosystem to environmental changes – even to the slightest changes in water temperature – because of their extremely high sensitivity. For this reason, they are considered an indicator or early warning system for the world's oceans, and perhaps a 'canary in the coal mine' for all of the other ecosystems on Earth.

Despite their importance – both as an ecosystem and barometer for environmental change – relatively little is known about coral reefs today. Remarkably, there is no comprehensive global baseline map of living coral reefs. Scientists do not even know the location of many of the world's reefs, much less their present condition or which species inhabit them. For example, in the Pacific, which has the greatest concentration of coral reefs in the world, it is estimated that 90% of these reefs have never been assessed.***** Given the paucity of data, it is impossible to measure the rate at which the reefs are disappearing with accuracy. By contrast, scientists know exactly how much rainforest is left and how much is being destroyed every day because there is a very detailed rainforest baseline provided by satellite imagery. A comparable baseline for coral reefs is urgently needed. Until this is achieved, we will not have the information we need to address the coral reef crisis on a global scale.

II. Taking A Global Approach to the Coral Reef Crisis

To address the crisis, coral reefs must be located, mapped, studied, assessed, preserved and where possible, restored in oceans worldwide. To date, most coral reef research and preservation efforts have been limited in scope – by region, country or specific reef. Yet because the crisis is global in nature, only a global approach will succeed in resolving it.

****Reefs At Risk, World Resources Institute, 1998***

To achieve this, immediate measures must be taken in the areas of science, research and technology, as well as in public education and international action.

In the scientific realm, a global "baseline" map must be established for all future coral reef research comparable to that which exists for the rainforest, and the means to monitor change must be developed to track the health of the world's coral reefs over time. Today, the best way to obtain an accurate, living map of coral reefs is through a multi-faceted approach combining *in situ* underwater photography, measurements and assessments – so-called 'ground-truthing' with 'real-time' satellite imagery. Yet satellite mapping and monitoring of coral reefs pose unique challenges. Unlike the rainforests, reefs are underwater and often not visible to the naked eye. In effect, the curtains of air and water above coral reefs must be removed to "see" them and detect change. This will only be possible through remote sensing – specifically by pioneering a special space-based coral reef sensor, the data from which will be transmitted by satellite and made available to the world via the internet.

In addition, new technologies must be developed and installed to reduce, and when possible, eliminate pollution of coastal habitats from sewage, industry and other sources. Damage to reefs from dynamite and cyanide fishing must also be stopped whenever possible. At the same time, Marine Protected Areas, coral reef preserves and sanctuaries must be maintained and expanded. Furthermore, methods for restoring reefs must be researched, developed, tested and expanded. Finally, to protect coral reefs worldwide, more comprehensive legislation, better management approaches and enforcement of existing laws must be implemented at local, national, regional and international levels. To achieve this, a well-coordinated international education and action campaign to build awareness about the coral reef crisis is imperative.

III. PCRF's Global Mission

PCRF's mission is to preserve and protect the earth's coral reefs through pioneering programs in science, technology and education. PCRF's mission objectives are to:

- Establish a comprehensive global baseline map of living coral reefs
- Track the health of coral reefs worldwide and provide quantitative information about the change in their health over time
- Pioneer new techniques for mapping and monitoring coral reefs using underwater observations and satellite imagery
- Provide coral reef field research experience and seamanship training to an international team of students aboard the 84' sailing research vessel *RV Heraclitus*, currently in the South Pacific
- Build global awareness about the coral reef crisis through innovative educational programs
- Promote action to preserve and protect coral reefs through an International *Save the Coral Reefs* Campaign
- Provide a new technology for wastewater recycling and management, Wastewater Gardens™
- Improve the technology for restoration of coral reef ecosystems

Since its inception, PCRF has made significant progress toward fulfilling its mission. To accomplish this, PCRF has assembled a prestigious team of scientific advisors including: Dr. Paul Coleman, Professor Emeritus of Physics at UCLA and recently retired President of the

Universities Space Research Association, Dr. Farouk El-Baz, Director of the Center for Remote Sensing at Boston University, Dr. Phil Dustan, Professor of Biology at the College of Charleston, coral reef ecologist and formerly a principal consultant to the U.S. Environmental Protection Agency on coral reefs, Dr. Sylvia Earle, Explorer-in-Residence at the National Geographic Society and former Chief Scientist for the National Oceanic and Atmospheric Administration (NOAA), and Bob Goeke, Chief Engineer at MIT's Center for Space Research.

IV. Coral Reef Field Research and the Research Vessel *RV Heraclitus*

A. Overview

To fulfill its mission, PCRF chartered the 84' research vessel, the *RV Heraclitus* to:

- Conduct on-site monitoring of the health and vitality of coral reefs worldwide
- Pioneer a method for mapping coral reefs using real-time satellite images
- Provide a permanent platform for ground-truthing assessments once a satellite dedicated to coral reefs is launched

To date, the *RV Heraclitus* is the only ship continually in the field studying and monitoring coral reefs on a planetary basis.

PCRF launched its research expedition on the *RV Heraclitus* in 1995 at Turneffe Atoll, Belize. Since then, the ship has sailed across the Atlantic Ocean and conducted studies in the Red Sea, Indian Ocean, Southeast Asia Sea and the South Pacific. Over the next ten years, PCRF will expand its expedition around the world to the following locations: Papua New Guinea, Solomon Islands, Japan**,** California Coast, South Pacific, Polynesia, Melanesia, Micronesia, Southeast Asia, Indian Ocean, Cape of Good Hope, Caribbean, Atlantic, Mediterranean and Red Sea.

At each coral reef site visited, the *RV Heraclitus* crew (to date composed entirely of volunteer officers, scientists and students from around the world) conducts research in several key areas. First, the crew performs extensive on-site filming, using a state-of-the art underwater digital video camera. To date, PCRF has amassed over 150 hours of film cataloging reefs worldwide, all of which are in the process of being digitized into single frames and transferred into a special software program for coral reef analysis designed by PCRF advisor, Dr. Phil Dustan, at the College of Charleston.

In addition, transect measurements are taken at each site, and the reefs are assessed for their health, vitality and species content. These data are recorded and sent to labs for further study by PCRF and its scientific advisors and are also available for students to analyze for Masters and Doctoral Dissertations at the College of Charleston.

A major milestone was achieved in January 2002 when Qamar Schuyler, Research Associate for PCRF and Masters student at the College of Charleston under the direction of Dr. Phil Dustan, joined the *RV Heraclitus* in Karong Kapota Atoll, Sulawesi, Indonesia. Schuyler brought special computer equipment for satellite image analysis of coral reefs on loan from the College of Charleston. Over the course of three weeks, the 15 member *RV Heraclitus* crew assisted Schuyler in a pioneering effort: correlating real-time *in situ* studies of the atoll's coral reefs with satellite imagery. Teams went out each day to record the different communities of

corals while taking a latitude and longitude position of their location using a Global Position System (GPS). They then returned in the evening to compare their findings with satellite images of the exact same reef logged into the computer program for coral reef analysis.

This was the first time research on board the *RV Heraclitus* was real-time: data were taken during the day and analyzed at night to create the first map of living coral reefs in the Southeast Asia Sea. Prior to this major research accomplishment, data were collected and sent back to laboratories in the U.S. for analysis.

B. Action Plan

During 2002, in preparation for the Coral Reef Satellite Mission *(please see p. 6, Section C. below)*, PCRF will expand real-time satellite mapping of coral reefs aboard the *RV Heraclitus* as follows:

1) Acquire and place a special computer and GPS electronic mapping system permanently on board the *RV Heraclitus*
2) Obtain additional existing Spot satellite images to study change in the coral reef ecosystem of Karong Kapota Atoll over time
3) Complete one more "proof of concept" study of coral reef real-time satellite mapping at a site to be visited by the *RV Heraclitus* in Papua New Guinea
4) Develop the research methodology for real-time satellite mapping of coral reefs
5) Analyze and publish the recent real-time satellite mapping of coral reefs in Karong Kapota Atoll as a reference for mapping of coral reefs in the Southeast Asia Sea
6) Support two graduate students on board the *RV Heraclitus* and then later at their respective institutions for mapping of coral reefs in remote locations of the world, analysis of the data, and publication of the study
7) Develop a satellite communication system on board the *RV Heraclitus* to support real-time facilitation of data flow, communications and image analysis

V. Remote Sensing of Coral Reefs

A. Mapping Coral Reefs From Space

To further its mission, PCRF has assembled an interdisciplinary team of advisors and scientists from a variety of institutions including: the College of Charleston, Linnaean Society (U.K.)**,** MIT, Scripps Institution of Oceanography, the Stevens Institute of Technology and USC. Over the past decade, at a series of workshops and conferences, this team has explored the question of whether it is possible to map coral reefs from space, detect change, and then monitor changes in their health and vitality conditions over time.

Using radioactive transfer theory, PCRF's team has investigated the upwelling optical properties of reef organisms, and results indicate coral reef signals can indeed be observed from space. (Lubin et al, 2001). In 1991, Dr. Phil Dustan, PCRF's Principal Investigator for the study of coral reefs, was the first to map coral reefs using satellite imagery, thereby proving it possible. Dr. Dustan's studies were conducted off the Florida coast, and he used

Lubin, D., W. Li, P. Dustan, C. H. Mazel, and K. Stamnes. 2001. "Spectral Signatures of Coral Reefs: Features from Space." Remote Sensing of Environment, 75, 127-137.

Spot satellite imagery (Dustan et al, 2000). Since then, the team on board *RV Heraclitus* has conducted ground-truthing operations on coral reef communities in Southeast Asia comparing actual surveys to Spot imagery. Further research is now underway which demonstrates how satellite imagery can be used to detect change in coral reef health through remote sensing (Dustan et al, 2002).

Although existing satellite technology, such as Spot, Landsat and Ikonos, has provided imagery proving the possibility of mapping and monitoring coral reefs from space, these images are far too gross to provide the level of quantitative and qualitative data necessary for creating a comprehensive map of living coral reefs or detecting and monitoring changes in their health on a global basis. These existing satellite systems do not possess the spatial, spectral or orbital specifications required for this purpose. Therefore, a specially designed coral reef sensor needs to be placed on a dedicated satellite to achieve this objective.

Additionally, for remote locations, satellites must be specifically programmed to acquire imagery, and until recently, reefs have not been considered important targets. For this reason, while single, gross images of coral reefs exist, these images are not acquired routinely but rather selectively and by chance – largely at the discretion of government agencies who happen to deem a tropical country or coastline of political or military significance. Thus, it is rare to find multiple useable images of individual reef systems – which are essential for mapping and monitoring them over time. Finally, even if it were possible to acquire all the existing satellite images necessary to cover the coral reef global area, these images would still be very imprecise for coral reef mapping and monitoring, and the cost to purchase these images – not including analysis and presentation – is estimated to exceed $50 million.

B. The Case for Remote Sensing of Coral Reefs

Remote sensing technology is the only means to supply the data necessary to map and monitor reefs on a global scale in a cost and time effective manner. Traditionally, reef health has been estimated using expensive and tedious underwater survey techniques that by definition cannot cover large areas. Remote sensing by satellite offers the potential to survey coral reef ecosystem health on a geographic scale not previously possible. This becomes even more important when one considers the remoteness of most reefs and the expense of expeditionary travel. However, it is not a simple task because coral reef environments are optically, spatially, and temporally complex. To extract meaningful information from satellite imagery, techniques must be developed to relate the electronic signals received by a spacecraft to the optical properties of the reef community and its associated biological processes.

Specifically, the myriad of beautiful colors on a coral reef are a mixture of the optical properties of plant and animal pigments, including the symbiotic *zooxanthellae* of corals, substrate characteristics, and the overlying water column (Dustan et al, 2000). Individual colors blend together with increasing scale, generating a larger scale collage that can be identified by spacecraft imagery. This signal becomes degraded as it passes through the

atmosphere and water due to the wavelength-specific selective absorption of light. This degradation can be partially mitigated if the properties of the air and water column are known, and accurate depth measurements can be correlated to the precise geographic coordinates of a geo-registered satellite image.

It is important to note that remote sensing in tropical environments is further complicated by the high probability of cloud cover, and clear scenes can be difficult to obtain. For this reason, multiple orbital passes by a satellite dedicated to the study of coral reefs are critical and an imperative for obtaining the data necessary to map and monitor them over time.

Time-series analysis – comparing multiple images of a single reef over time – shows the variability of the upwelling signal of the reef. While a single image provides only a snapshot of the reef, a time series analysis can provide the data needed to validate the mapping of the reef and its communities, track changes in coral community structure and health and make predictions about the future health and composition of the reef. Such an analysis can distinguish daily and seasonal variability from larger community scale ecological degradation. In order to accurately interpret the images, we need to understand the effects of both natural and human-induced change on the upwelling signal from a reef.

Presently, the most complete coral reef time series exists for the Florida Keys. Using twenty-two Landsat images of the northern Keys from 1982 to 1996, a team led by Dr. Dustan has performed an analysis of pixel-scale variation through time, termed 'temporal texture.' Using both Landsat satellite images and *in situ* observations, this team has shown that the process of reef degradation has altered both the spatial patterning and variability of pixel brightness, which can be identified in unclassified Landsat imagery (Dustan et al, 2002).

C. Coral Reef Satellite Mission

In Fall 2001, PCRF signed a Teaming Agreement with Massachusetts Institute of Technology's (MIT's) Center for Space Research (CSR) to collaborate on a Coral Reef Satellite Mission. Under the terms of this agreement, PCRF has contracted with MIT to oversee the entire space mission from design and development to operations management. A Coral Reef Satellite Mission Description Document (MDD - a comprehensive funding proposal) is currently being developed and will be completed in Fall 2003. Principal Investigator Dr. Phil Dustan is directing the Science Team's work and Robert Goeke is overseeing the engineering team's work on the MDD. To date, all members of PCRF's Satellite Science and Engineering Team have contributed their expertise and time to this mission on an entirely pro bono basis. Once the MDD is complete, PCRF will raise the funding necessary for the mission. Principal members of PCRF's coral reef satellite team are:

Ed Boyle, Professor, Department of Earth, Atmospheric and Planetary Sciences, MIT
John Doty, Research Staff, MIT Center for Space Research
Phil Dustan, Professor, College of Charleston, South Carolina
Robert Goeke, Chief Engineer, MIT Center for Space Research
Dale Kiefer, Professor, Department of Biological Sciences, University of Southern California
Dan Lubin, Research Physicist, Scripps Institution of Oceanography
Knut Stamnes, Professor, Stevens Institute of Technology

The Coral Reef Satellite Mission will provide real-time data which will be made freely available to governments and scientists, as well as to international organizations such as the U.N., other non-profit environmental groups, fisherman, educators, activists and interested people all over the world. The primary means of disseminating the information will be via the internet, providing curricula for all ages, and producing products such as maps, computer programs, games, etc. The mission will also provide scientific data at no cost that can be used by scientists, teachers and students for their studies, as well as alerts to managers and the world community of all detectable sources of coral reef devastation – ranging from coral bleaching on even the most remote reefs to dynamiting and sewage dumping. Even a cruise ship dumping sewage illegally could be spotted and identified by the satellite as it passes overhead.

PCRF's Coral Reef Satellite Mission will give the world the information urgently needed to preserve and protect coral reefs worldwide for the very first time. It will also be the first satellite mission dedicated to stewardship of the earth, thereby setting a precedent for the use of space for the benefit of earth's environment. In addition, it will provide a prototype biospheric environmental monitoring program that involves the people of the world and that can be used as a template for monitoring other components of earth's environment, such as tropical and temperate forests. As such, the Coral Reef Satellite Mission has the potential to serve not only as the cornerstone of a global educational and action campaign for coral reefs, but also as a model for the preservation of our planet's natural resources.

D. Action Plan

During 2002, in preparation for the Coral Reef Satellite Mission, PCRF's team will achieve the following:

1) Refine the scientific requirements of the mission, specifically:
   - Number of visible bands and width of each band
   - Radiometric accuracy requirements of each band
   - Spatial accuracy requirements/size of individual pixels
   - Observation schedule requirements (i.e., how many reefs to image per orbit, data down-loading schedule, optimal time of day for image capture, etc.)
   - Algorithm needs and how to fulfill them
   - Ground processing requirements for different users and timeliness of each product
2) Refine the instrument design for the coral reef sensor
3) Sponsor a working conference for the satellite team to further objectives #1 & #2 above *(Completed 4/02)*
4) Prepare a Solicitation to Industrial Partners (Spacecraft Vendors), review their bids and select a space vendor
5) Complete the Coral Reef Satellite Mission Description Document (Funding Proposal) and commence the process of funding the space mission
6) Recruit and hire the Managing Director for the Coral Reef Satellite Mission
7) Identify the users, products and applications for the information to be provided by the Coral Reef Satellite Mission

VI. PCRF's International *Save the Coral Reefs* Campaign

A. Overview

The goals of this campaign are:

1) To inspire in people everywhere a love and respect for coral reefs and their abundant life
2) To reach as many people as possible, of all ages, from all backgrounds, in all parts of the world about the coral reef crisis
3) To encourage action to preserve and protect coral reefs worldwide

To achieve these goals, PCRF is forming strategic alliances with people and organizations interested in or already working to preserve reefs. We will continue to forge alliances for this purpose and encourage collaborative efforts to build a coalition among citizens, as well as governmental and non-governmental organizations to achieve better reef resource management, expanded national, regional and international legislation, and ultimately the ratification of a worldwide treaty.

B. Building Blocks of the *Save the Coral Reefs* Campaign

The first step in this campaign is to build awareness about the coral reef crisis through educational materials, museum exhibits, film, print media, high profile events and other forms of outreach. To this end, PCRF has developed "Main Messages" which are integrated into every aspect of the campaign. These messages are:

- Earth is an ocean planet
- Coral reefs are the barometer of the ocean's health
- The world's coral reefs are dying at an alarming rate
- A comprehensive baseline map of living coral reefs is urgently needed
- There are solutions to the coral reef crisis
- You Can Make A Difference in Saving Coral Reefs

C. Coral Reef Curriculum – *RV Heraclitus* Model

Over the past decade, PCRF has developed an innovative educational program for students aboard the *RV Heraclitus.* To date, approximately 100 young people from around the world have had the opportunity to participate in the *RV Heraclitus*' unique and historic voyage to monitor the world's coral reefs. Rotating every nine months, these students:

- Learn how to assess healthy, damaged or endangered reefs
- Learn how to conduct underwater field research
- Make a concrete contribution to the mapping and monitoring of coral reefs using satellite imagery and thereby make a difference in their ecological future
- Gain direct experience in all aspects of seamanship

- Learn how to overcome challenges at sea and cooperate as a team with fellow members from cultures very different from their own
- Discover and interact with local peoples in all the diverse, remote and exotic cultures the *RV Heraclitus* visits

Using this student program on the *RV Heraclitus* as a model, PCRF is developing an innovative Coral Reef Curriculum, which not only provides substantive content about the crisis and possible solutions, but also offers concrete ways for individuals to become involved in a global campaign to save coral reefs. The curriculum is intended for use by people of all ages, from all cultures, in schools, community and religious organizations, as well as by activists, scuba divers, snorkelers and other eco-tourism enthusiasts around the world.

Users of the Coral Reef Curriculum will become passengers on an adventure to breathtaking reef locations around the world through a film featuring highlights of PCRF's expedition. These sites include coral reefs off the coasts of: Egypt, Oman, the Maldive Islands, the Seychelle Islands, Kenya, Bali, the Sulawesi Islands, Vietnam and the Papua New Guinea and Solomon Islands.

The *RV Heraclitus* crew will be guides, celebrating the exquisite beauty of coral reefs, while introducing the abundant biodiversity of these underwater gardens and conveying the important role these species play in supporting life in the ocean biome. The crew will also take passengers on dives to destroyed and endangered reefs, in each case explaining the source of the damage, such as: disease, dynamite fishing, bleaching, or algae overgrowth of coral tissue due to pollution from sewage or other sources. The crew will explain the VITAREEF criteria for assessing the health and vitality of any coral reef. Passengers will receive a coded VITAREEF Guide and become empowered to determine the status of any coral reef in the world: whether it is healthy or unhealthy, and if unhealthy, commence the process of determining what the source of the problem might be.

Passengers will also discover that coral reefs are the barometer or indicator ecosystem for the ocean, that they are vanishing and face possible elimination from most areas of the planet by the turn of the next century. Passengers will accompany the *RV Heraclitus* crew on dives where they are taking transect measurements and recording species content as well as other data critical for creating a map of the world's living coral reefs. Passengers will also learn there is currently no comprehensive baseline map of living coral reefs against which to measure their rate of disappearance, health and vitality over time, just why this is so urgently needed and how a Coral Reef Satellite Mission will make this possible.

By the end of the journey, all passengers will have the opportunity to:

- Develop an appreciation for coral reefs and the critical role they play on planet earth
- Learn about the coral reef crisis
- Participate in coral reef research
- Learn about satellite mapping and monitoring of reefs
- Become coral reef monitors
- Learn about solutions to the coral reef crisis

- Learn how to make a difference by joining an international *Save the Coral Reefs* campaign

In addition to the film, the Coral Reef Curriculum will contain:

- A 24-page booklet about coral reefs and their endangered status, complete with bibliography and references for further information on the subject
- A 16-page teacher's discussion guide with suggested lesson plans
- A 16-page student workbook
- A laminated VITAREEF ID Guide
- A *Save the Coral Reefs* color poster showing photos of healthy, barren and endangered reefs

Lively, thought-provoking questions and exercises in the discussion guide and workbook will be tailored to various age groups ranging from: Pre-K through Primary School, to Middle and High School, to Adult. A range of public outreach activities will be suggested to offer users concrete ways to make a difference in the *Save the Coral Reefs* campaign.

Examples of such activities include:

- Interviewing family members, friends, neighbors, as well as civic and community leaders about coral reefs and the current crisis
- Sponsoring a "teach-in" day about coral reefs at schools, places of worship, or community organizations for parents, civic leaders and the community-at-large
- Conducting letter writing campaigns to community, government and world leaders (sample letters will be included in the workbook) to provide information about the coral reef crisis, the urgent need for a comprehensive baseline map of living coral reefs and satellite mission, as well as call for better management practices, legislation and treaties for their preservation and protection
- Encouraging schools, businesses, and inland water and coastal communities to build Wastewater Gardens
- Promoting “reef-saver” fish and seafood
- Promoting reef safe diving and tourism
- Using the VITAREEF Guide to become a coral reef monitor at sites around the world
- Volunteering time to preserve and protect coral reefs
- Learning more about PCRF’s coral reef research and ways to get involved in the *Save the Coral Reefs* campaign by visiting our web site, www.pcrf.org
- Supporting organizations like PCRF that are working to preserve and protect reefs
- Sponsoring a day on the *RV Heraclitus*
- Encouraging their communities to host *The Coral Reef Crisis: Meeting the Planetary Challenge***,** an exhibit concept designed for PCRF by a team of leading museum, educational and visitor attraction specialists. An immersive and interactive experience, the exhibit is designed to inform visitors about the coral reef crisis, inspire them to become reef stewards and join the *Save the Coral Reefs* campaign. A detailed proposal outlining this exhibit is available and currently under consideration by several leading institutions including: the Los Angeles Museum of Natural History, the Vienna

Museum of Natural History, The Singapore Zoo and AquaFalls, an aquarium under construction in Niagara Falls, New York

- Adopting a coral reef for restoration

D. Action Plan

During 2002, PCRF will take the following steps with the Coral Reef Curriculum:

1) Complete the design and development of a prototype curriculum
2) Select a diverse group of schools for field-testing the curriculum in the U.S. and other English-speaking countries
3) Place the prototype curriculum, student and teacher evaluations on a secure web site for downloading by field-testing teachers
4) Commence the field-testing process

In 2003, PCRF will take the following steps with the Coral Reef Curriculum:

- Review teacher and student evaluations, and make necessary revisions
- Publish the curriculum for distribution in 1000 English-speaking classrooms (approximately 25,000 students)
- Complete a web site upgrade for the Coral Reef Curriculum which will be interactive, and link together students, teachers and others using the curriculum, providing them with: additional reference information, updates from the *RV Heraclitus* crew, as well as news about PCRF research, special events, the Coral Reef Satellite Mission and other opportunities for expanded involvement in the *Save the Coral Reefs* campaign

The ongoing nature of PCRF's research on the *RV Heraclitus*, constantly in remote and exciting coral reef locations, provides a variety of additional possibilities for expanding the Coral Reef Curriculum and our educational outreach program over time.

These include:

- Regular *RV Heraclitus* web site updates featuring reports and alerts on reef conditions, research findings, the cultures connected to the reefs and the crew's adventures-at-sea
- Seminars and special events when the *RV Heraclitus* crew arrives in ports
- Special event live satellite links to the *RV Heraclitus*

E. *Save the Coral Reefs* Events Bring World Attention to the Crisis

PCRF is creating high profile events to put the coral reef crisis on the map of public awareness. Organized by PCRF's media and event team, these efforts are entirely underwritten by sponsors and funded outside of PCRF's Annual Operating Budget. These events support and tie into all of the other aspects of the *Save the Coral Reefs* Campaign. *(For further information about these events, please see Appendix II.)*

VII. Pioneering Technology

A Wastewater Garden at the Sunrise School, Bali

A. Wastewater Gardens™ – a 100% Ecological Solution to Sewage Pollution

Since its inception, PCRF has also taken concrete steps to reduce sewage pollution of coral reefs by designing, testing and installing Wastewater Garden technology for this purpose. These Wastewater Gardens are a 100% ecological, low cost, low maintenance solution to the problem of human waste and completely eliminate the problem of sewage pollution – one of the greatest sources of reef devastation – wherever they are installed. Using no mechanical or moving parts and no chemicals, all wastewater is recycled via a gravity system into elegant, biodiverse gardens that produce lovely flowers as well as fruit and vegetables that can be eaten by humans and fodder crops for animal consumption. The systems are carefully sealed so that no wastewater contaminates the soil, ground water or coastal waters.

PCRF has successfully installed Wastewater Gardens in Mexico, the Bahamas, Bali, the U.S., Australia, and is currently adapting the technology to sites outside of London, in Singapore and in the Carpathian Mountains in Poland. To date, the largest Wastewater Garden installed by PCRF is located in the Xpu-Ha EcoPark near Akumal, Mexico and handles the effluent produced by up to 1500 visitors a day.

B. Action Plan

During 2002, PCRF will expand its Wastewater Gardens program as follows:

1) Increase installation of Wastewater Gardens in countries around the world including: Bali, Poland, Bahamas, the U.S., the U.K., as well as in aboriginal communities
2) Build public awareness about the need for and importance of Wastewater Gardens by upgrading the PCRF web site and by increasing presentations and distribution of brochures

3) Locating a site for the first demonstration Wastewater Garden in California *(Discussions have commenced for possible sites at the Los Angeles Museum of Natural History and Esalen Institute in Big Sur)*

VIII. Conclusion

Over the past decade, PCRF has amassed an enormous wealth of data and experience in the areas of mapping and monitoring of reefs, reducing sewage pollution, exploring possibilities for reef restoration and developing a unique and empowering educational program about coral reefs and their endangered status. As the coral reef crisis grows in urgency, the alarm bell has sounded, and we are now living in a time that could well determine the fate of coral reefs.

At this turning point, PCRF is uniquely poised to expand its efforts in the areas of science, research and applied technology as outlined above and to expand its *Save the Coral Reefs* campaign to spark interest, build awareness and encourage people of all ages to take action by offering them concrete ways to make a difference in preserving and protecting coral reefs worldwide. To achieve these critical objectives, PCRF needs support as outlined in the attached budget.

RV Heraclitus, PCRF's 84' sailing vessel

Today. My senses are wide open. We are giving a small performance in the island village tonight with slides. A Gilbertese settlement. Two days of safety training, dive rescue training and then hard on science…. Sad bleaching situation…. It is a race. They [the coral reefs] are disappearing at the speed of light.

– Michel Lippitsch, Expedition Leader, *RV Heraclitu*s

The eyes of Heraclitus guide us through the blind squalls at night, and by day, the endless shimmering mirage. Occasionally benevolent, the sea gods yield fish for our bellies and dolphins and whales for our spirits. Life is never boring, rather a continuous and occasionally unimaginable drama with the plotline withheld from the characters. It is this element of uncertainty and the wide open eyed vividness of the lives that entangle us, that, along with other more scientific elements, inspire us to make our journeys, to take these chances to greet our world, or worlds within worlds and gradually, hopefully, through the open sea, understand some part of it.

– Rich Moss, Chief Engineer, *RV Heraclitus*

Appendix I: *Save the Coral Reefs* Campaign High Profile Events

In June 2001, PCRF launched a Celebrity Sailboat *Race for the Reefs* in Los Angeles. James Cameron, Director of the movie *Titanic*, served as Honorary Chairman for this event. In his speech, he very eloquently outlined the critical role coral reefs play in the life of the oceans and just what is at stake if their soaring death rate is not reversed. He said,

"Our destiny is interlocked with the destiny of the sea.
If the seas die, we die."

Thanks to Mr. Cameron and his celebrity friends, the event and the coral reef crisis garnered world media attention in publications such as the *Los Angeles Times* and *People Magazine* and on television shows such as *Entertainment Tonight (please see attached articles).* Mr. Cameron will again be serving as Honorary Chair for our next Celebrity *Race for the Reefs* in Los Angeles in Fall 2003, to tie-in with the arrival of PCRF's research vessel *RV Heraclitus,* which will have just completed a dramatic voyage across the Pacific.

In our efforts to forge alliances with organizations interested in or working to preserve reefs, at the 2001 Celebrity *Race for the Reefs*, PCRF welcomed representatives from the Natural Resources Defense Council, the Institute of Ecolonomics, the Campaign to Save America's Resources, Women of Los Angeles, Women of Washington and Reef Check. It is with organizations such as these that PCRF will build a coalition among citizens, governmental and non-governmental organizations to achieve better reef resource management, expanded national, regional and international legislation, and ultimately the ratification of a worldwide treaty.

Appendix III: Sources of Support for PCRF – A Partial List

To date, PCRF has received grants, donations, in-kind contributions and other support from a variety of universities, foundations, corporations, institutions, government ministries and individuals around the world. These include: NASA; Seven Springs Foundation; The Lear Family Foundation, Directorate General of Tourism, Jakarta; National Geographic Asia Television; University of Singapore and the Aseanearean Expeditions; U.S. Embassy of Hanoi, Vietnam; Institute of Nha Trang, Vietnam; Centro Ecologico Akumal, Mexico; The Ann and Robert H. Lurie Family Foundation; Educational Enrichment Foundation; Ministry of Fisheries and Agriculture, Maldives; Office of the President, Kenya; Kenya Wildlife Service; Seychelles Marine Parks Authority; Princess Basma Bint Ali, Jordan Royal Ecological Diving Society; Prince Hilal M. Busaidi, Ministry of Agriculture and Fisheries, Sultanate of Oman; 2111 Foundation; Explorers Club; Wallace Genetic Foundation; Pacific Gateway Foundation; ENEA-Science Institute, La Spezia, Italy; Oceanic Inc., USA; Raytheon Corporation; Bali Marina; Raffles Marina, Singapore; Patagonia, Inc., USA; American Presidents Line, USA; Shell Australia; Royal Australian Navy; Rotary Club, Australia; Sacred Mountain Sanctuary, Sideman, Bali; Nautica International, Inc., USA; Mobile Oil Kenya Limited; Panasonic, USA; Aqua Dynamics, Sri Lanka; Raj Shipping Agencies, India; The Body Shop, Oman; British Airways, Oman; PEPSI, Oman Refreshment; West Marine, RayMarine, Raytheon, Detroit Diesel, Body Glove and Oceanic.

For a more complete list of PCRF's donors and sponsors, please visit our web site, www.pcrf.org