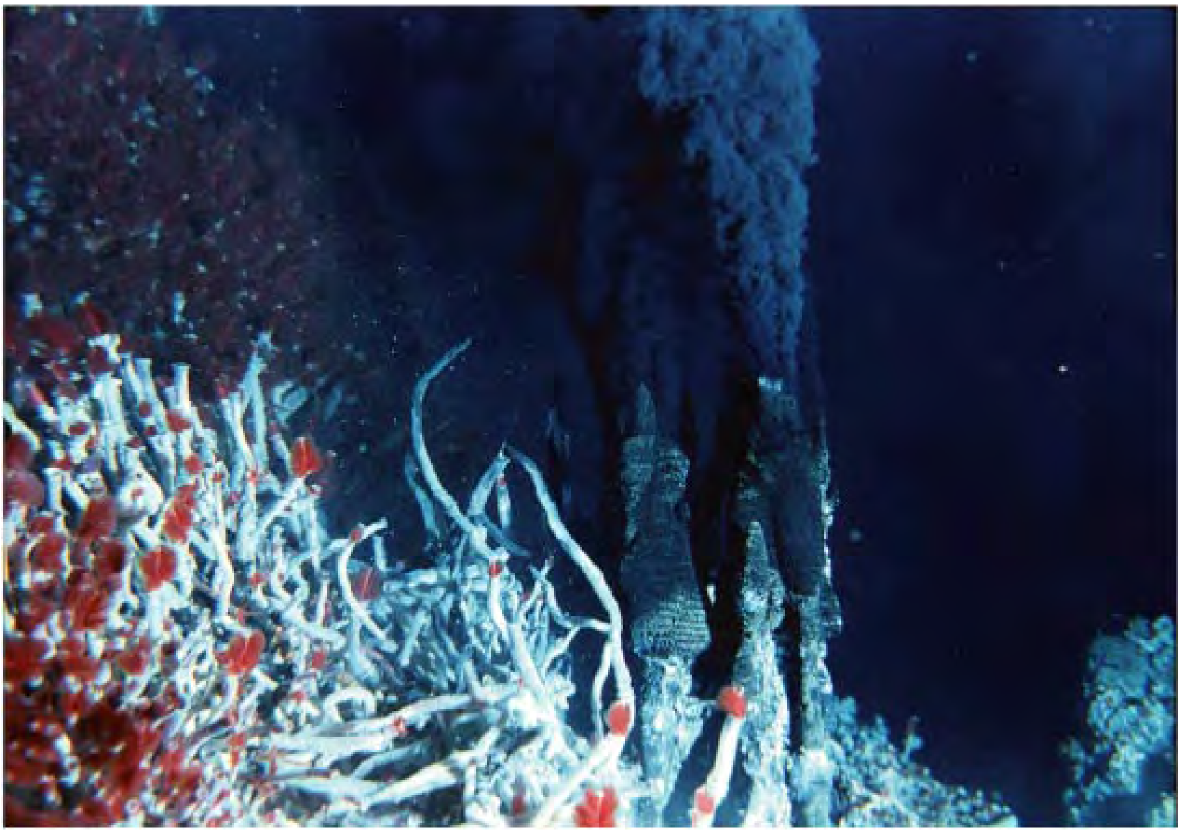
Management and Conservation of Hydrothermal Vent Ecosystems



Report from an InterRidge Workshop,
Institute of Ocean Sciences, Sidney (Victoria), B.C., Canada
28 – 30 September, 2000

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Report from the InterRidge Workshop: Management and Conservation of Hydrothermal Vent Ecosystems

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28 – 30 September, 2000

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InterRidge, Japan
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Summary

This report presents the first formal consideration by the international scientific community of the threat to the isolated hydrothermal vent "oasis" ecosystems from human activities. The aim of the report is to increase awareness among all potential users about the importance, fragility and potential value to society, through sustainable exploitation, of hydrothermal vent ecosystems. It is recognised that human impact on these ecosystems will only increase in the future and that gaining knowledge about them is crucial to sensible management or conservation policies. Because of the current poor understanding of these unique ecosystems, a conservative and precautionary approach is suggested to proposals for future use. The major findings of the report [with page numbers] are listed below. A section proposing measures for conservation and sustainable use begins near the end of the report on page 25.

Major Findings

- Deep-sea hydrothermal vent sites are sensitive because of their high percentage of endemic species and the unique nature of many of the species found there [10].

- Many shallow water hydrothermal vent sites are "hot spots" of species biodiversity. These sites should be preserved as areas from which recolonisation of other sites in the coastal zone can occur [11].

- Several sites are already under potential threat from either intensive scientific exploitation or future mining activities [15-16].

- The management of "threats" to hydrothermal vents should invoke the concept of "sustainable use" through which the components of the ecosystem are utilized in ways and at rates that do not lead to long term declines in diversity [16].

- The management of all of the world's marine hydrothermal sites is an unrealistic goal so that criteria should be developed for identifying those hydrothermal vent sites of critical importance and those that are particularly sensitive to disturbances because of their scientific value or significance for species survival [10].

- Nations who are contracting parties to the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Biological Diversity (CBD) have obligations to protect and preserve the marine environment and rare or fragile ecosystems and to conserve biological diversity and to use its components sustainably. In order to fulfil their obligations under UNCLOS and CBD, nations should identify biological communities associated with hydrothermal vent systems and regulate activities to eliminate or minimize impacts on vent biodiversity [15]

- Within areas of national jurisdiction, the Convention on Biological Diversity (CBD) requires marine scientists and bioprospectors to obtain the "prior informed consent" of the relevant nation as a condition of access to these areas for the investigation of genetic resources. The United Nations Convention of the Law of the Sea (UNCLOS) requires the "consent" of the relevant nation for marine science activities within areas of national jurisdiction [19].

Introduction

This report presents the results of an international workshop held at the Institute of Ocean Sciences in Sidney, British Columbia, Canada from September 28-30, 2000, on the management of marine hydrothermal vent ecosystems. The workshop was co-sponsored by the InterRidge Office, the Natural Sciences and Engineering Research Council of Canada, the Department of Fisheries and Oceans Canada, the Marine Policy Center of the Woods Hole Oceanographic Institution and the US RIDGE office. The primary goals of the workshop were to:

1) Discuss the environmental effects of various uses of vent ecosystems
2) Establish rationale for conservation of vent species and their habitat
3) Consider criteria for identifying uniquely sensitive sites
4) Develop recommendations for management
5) Discuss and draft management plans for high-use vent sites
6) Make recommendations for conservation research

Background

The discovery of chemosynthetic-based ecosystems at hydrothermal vents in the deep ocean was one of the most important findings in biological science in the latter half of the 20th century. More than 100 vent fields have been documented along the 50,000 km global mid-ocean ridge system. At this time, over 500 new animal species, over 80% of which are endemic to the vents, have been described from this environment[1]. Unusual, highly-evolved symbioses between invertebrates and chemolithautotrophic bacteria are common at vents, producing concentrations of biomass that rival the most productive ecosystems on Earth. The predominance of chemoautrophic and hyperthermophilic microbes in hydrothermal vent waters has stimulated new theories of the origin of life on Earth. It has also prompted astrobiologists to seriously consider geothermal energy as a viable power source for biosynthesis and maintenance of carbon-based life forms on other worlds.

Hydrothermal vent science is now in its third decade of discovery. The research focus is shifting to time series observations, and long term studies are being undertaken by organisations in several countries. These latter developments are resulting in the concentration of sampling, observation and instrumentation at a small number of fixed "observatories". The potential returns from co-ordinated, multidisciplinary time series studies of this type are tremendous.

It is becoming apparent, however, that an important element of this co-ordination of research will involve resolving and avoiding conflict between different types of field investigations. Already, effects of sampling operations on vent faunal communities have been documented[2,3]. As observatory type studies expand, so will the potential for conflict between the needs of purely observational investigations and those of *in situ* experiments and instrumentation and the removal of specimens for collections and laboratory studies. Concern about the impact of scientific research at vents goes beyond the resolution of conflicts between different styles of investigation. Species conservation and environmental stewardship are also issues of particular concern to vent scientists. Hydrothermal faunal communities occupy very small areas of the seafloor and many sites contain animal species found nowhere else. As vent sites become the focus of intensive, long-term investigation, oversight organisations will need to introduce mitigative measures to avoid significant loss of habitat or over sampling of populations.

Hydrothermal vents are also found in shallow water (<300 m depth) in areas such as the Kuriles; Japan; New Britain, Papua New Guinea; Vanuatu; New Zealand; Baja California; LA County, California; Iceland; the Açores; Italy and Greece. Few shallow vent sites have been studied in detail to catalogue biological diversity. The data to date suggest that, in contrast to deep sea vents, shallow vents, in general, have few endemic species of metazoa, and a low biomass but a high diversity of macroepifaunal species, often more than surrounding areas. This is true both for exposed coastal sites, sheltered calderas, and submarine caves with geothermal springs. The shallow water vents also support a large number of species of diatoms, macro-algae and thermophilic and hyperthermophilic Archaea and Bacteria. Many of these sites may be regarded as 'hotspots' of species biodiversity.

The reason for high species biodiversity at shallow water vent sites is unclear, although it is probably a consequence of the diversity of ecological niches available due to the great range of physical and chemical conditions present. Sites with the greatest number of species have both hard and soft seabed as well as a variety of venting fluids, including varying water salinities. Study of temperature adaptations by ecosystems at coastal vent sites may indicate how the biota in coastal waters will respond to global warming. Such accessible sites are obvious candidates for long-term monitoring stations.

Scientific research is not the only present or impending source of human impact on hydrothermal vents. The spectacular nature of black smoker chimneys and abundant animal life under extreme conditions are draws for eco-tourism. In the summer of 1999, a Seattle-based tour operator, in collaboration with Russian scientists, staged a series of joint science-tourist dives to the Rainbow hydrothermal fields of the Mid-Atlantic Ridge using the Russian Mir submersibles. The dives were conducted in international waters without need for clearance by any governing body concerned with the protection of vent habitat or biodiversity. More tourist dives are likely to follow. Of greater concern is recent interest in seabed mining and bioprospecting at seafloor hydrothermal vents. A few months prior to our workshop, an Australian-led expedition to the Bismarck Sea north of Papua New Guinea dredged seafloor vents, prospecting for minerals and micro-organisms of potential economic value. The mining industry has long maintained an interest in base metal deposits at hydrothermal vents since many are analogues for deposits being mined on land[4]. This interest is now resulting in exploration activity. Exploration claims have been granted to one mining firm, in the large vent fields of the southwest Pacific, an area also noted for a high degree of vent faunal endemism. In June 2000, the International Seabed Authority, a United Nations organisation that regulates development of seabed mineral resources outside of national jurisdictions, hosted a workshop on the development of two groups of seabed resources, one of these included the polymetallic sulphide minerals found at hydrothermal vents. These signs of increasing scientific and industrial activity in the vent environment prompted InterRidge to sponsor a workshop on the management of all human activities in this environment.

Workshop Organization

The themes and overall goals of the vent management workshop were developed by a 16 member organising committee composed of biologists, geologists and marine policy experts from InterRidge member countries. The detailed organisation of the scientific content of the workshop and the compilation and editing of this report have been the responsibility of the two co-ordinators, Kim Juniper (U. Québec, Montréal) and Paul Dando (U. Wales - Bangor).

The workshop program was developed to emphasise open discussion and working group sessions rather than lectures by invited speakers. Invited talks were scheduled in the first two days to provide background and overview information for the discussion and working group sessions that followed.

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The Rationale for the Preservation of Vent Ecosystems

These discussions touched on the *raison d'être* for the workshop yet were the most difficult to place within a critical and objective framework. Most participants were able to invoke valid scientific or socio-economic arguments for the protection of vent ecosystems, and a long list of important points was produced. Below we list these points within a 'Use-value' and 'Non-use Value' framework, similar to that used in the biodiversity conservation literature[1,2].

Non-use values

Existence Value - knowledge of the continued existence of a species or ecosystem

This value is perhaps more important in the case of inaccessible areas such as the deep ocean where members of the general public are unlikely to visit. Development of the existence value of remote ecosystems and species requires a public education effort by those who do have access.

Bequest Value - leaving use and non-use values to following generations

There is a basic requirement under the Convention on Biological Diversity to conserve biological diversity for evolution and for maintaining life-sustaining systems in the biosphere. Many shallow vent sites, although they have few endemic species, are 'hot-spots' of species biodiversity due to the wide range of environmental conditions found. Such sites should be preserved as areas from which re-colonisation of other sites in the coastal zone can occur. In contrast, most species living at deep-sea vents are endemic to them.

Hydrothermal vents will be an important focus for future research and technological development. The inherently interdisciplinary nature of scientific research at hydrothermal vents fosters new advances in science by bringing together scientists from different disciplines who would not otherwise meet and work together on common problems. The 'spin-off' from these collaborations is extensive and will lead to developments in other areas of science and technology. One example is that the engineering necessary to develop sensors and instruments for use under the high temperatures and pressures at mid-ocean vents will be directly applicable to problems in the chemical industry.

Use Values

Option Value - potential use values

Vent organisms may prove to have a large biotechnological potential, in terms of both enzymes and specialised compounds. Adaptations to high temperature are a continuing focus for research, as are adaptations to other extreme conditions. In an example of the latter, some vent organisms are known to survive under highly radioactive conditions, resulting from the presence of radionuclides in polymetallic sulphide deposits. The study of such organisms may lead to the discovery of new DNA repair mechanisms that could be of use in medicine. Similarly, the tolerance of vent organisms to high heavy metal concentrations may find beneficial applications in bio-remediation, allowing the recovery of badly polluted sites.

Direct Value - value gained directly from the resource

Earth sciences: Apart from the immediate commercial value of hydrothermal mineral deposits, geological and geochemical research at hydrothermal vent sites will permit us to better understand the genesis of ore deposits and improve models for exploration for ores on land. Studies peripheral to the vents themselves are providing new geological knowledge about the formation, structural deformation and aging of the Earth's volcanic ocean crust and associated sediments. Furthermore, the present distribution of vent organisms reflects past plate tectonic movements and can help us to trace the tectonic history of the Earth[3].

Biological sciences: The study of vent organisms is also opening our minds to previously overlooked biological phenomena elsewhere on the planet. For example, the realisation that many vent animals lived on chemosynthesis *via* symbiotic associations with bacteria directly led to the discovery of similar ecosystems in reducing sediments world-wide.

We have only a basic knowledge of fundamental biological systems and physiological processes, including the early evolution of the eukaryotic cell. A very wide range of life forms can be studied at hydrothermal vents, contributing to a better understanding of basic life processes. Vent species have evolved to survive frequent habitat extinctions and extreme habitat instability. Study of their ecology and life history strategies should lead to a better understanding of species characteristics that permit success in ephemeral habitats.

Studies at submarine hydrothermal vents are helping to define the limits to life under extreme conditions. Abiotic synthesis of organic compounds under the conditions found at hydrothermal vents may give clues to prebiotic molecular behaviour as well as to the origin of life and help in astrobiological predictions of which planets are likely to have evolved life forms.

Public Education: Vent ecosystems are visually spectacular, extreme environments, that have generated widespread public interest. They are a resource that can be used to inform the public about science, scientific problems and the way in which scientists work.

Indirect Value - value gained indirectly from the resource

Geochemical cycling: Submarine hydrothermal vents are important in the geochemical balance of the planet due to their output of chemicals[4]. All sea water re-circulates through the vents on average every 10^7 - 10^8 years and through the hydrothermal plumes every 10^3 - 10^4 years. Vents contribute to ocean productivity and the heat flux affects the local circulation of seawater.

Refuge for relict species: Deep-sea hydrothermal vents contain a large number of endemic and unusual species and serve as refuges for close relatives of ancient forms of life. They show a unique range of habitat diversity such that adaptations of organisms to some vent niches are not, today, paralleled at other sites on the planet. Vent organisms have the genetic potential to grow and survive at the extremes of environmental conditions that have been present at various times since the beginning of life on Earth.

Understanding environmental change: At shallow vent sites, coastal species have adapted to toxic conditions (low oxygen, high hydrogen sulphide and heavy metal concentrations) and high temperatures. A study of these organisms could help us predict how coastal ecosystems may respond to increasing anthropogenic pollution and global warming.

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Exploitation of Hydrothermal Vent Sites and Threats to Vent Ecosystems

Definitions of Threats and Uses

A *threat to a vent ecosystem* may be defined as an activity that will compromise sustainable use of the ecosystem, or diminish, or adversely affect, the use or value of the resource.

Biological diversity, or *biodiversity*, as defined in Article 2 of the Convention on Biological Diversity means the variability of life in all forms, levels and combinations, that is to say variability within species (genetic diversity), between species (species diversity) and of ecosystems. In a more tangible sense, relevant to management of vent sites, this means gene pools, species, populations and ecosystems[1].

Exclusive uses, such as mining or some major research installations, will prevent other uses from occurring. Such activities preclude realisation of the value of the resource for other users. Some exclusive uses, *e.g*. reserves for observation only and marine protected areas, may not measurably affect biodiversity or habitat integrity.

Inclusive uses allow other uses of the vent site to occur. Inclusive uses, which, in certain circumstances, may compromise sustainable use, include:

- Biological or substrate sampling that measurably diminishes biodiversity
- Uses releasing toxins, generating noise or light or depositing waste
- The introduction of exotic species
- Activities affecting the habitat, *e.g.* drilling affects sub-seafloor hydrology and may divert vent fluid flow away from vent communities.

Forms of Exploitation

Scientific exploitation of hydrothermal vent sites

Impacts arising from scientific studies at hydrothermal vents include direct impacts leading to habitat loss and organism mortality as a result of:

- Removing chimneys and rocks for geological investigations or chemical sampling.
- Environmental manipulation, such as drilling, which can change fluid flow pathways and shut off the supply of fluids to colonies of vent organisms.
- Clearing fauna, *e.g*. for experimental studies on recolonisation or collecting fauna for biodiversity or population studies.
- Transplanting fauna between locations.
- Placement of instrument packages that may disturb fauna and change water flows.
- Observation, *e.g*. deleterious effects of light on photosensitive organisms.
- The use of manned submersibles and remotely operated vehicles can damage fauna by landing on them or causing damage by the use of thrusters.

Scientific activities, such as those listed above, also can cause second order biological effects including:

- A decrease in population numbers
- Local extinction of species
- Regional or global extinction of species
- A change in community structure
- The introduction of exotic species carried by underwater vehicles from another site

Most scientific activity is concentrated at a relatively small number of vent sites that are visited repeatedly. There is a real need to minimise adverse effects of sampling on observational studies. Knowledge of the population size, population dynamics and genetic structure of populations is needed in order to define an acceptable harvesting rate of organisms for laboratory studies. Managing the impact of scientific activity also will require an understanding of how species interact with each other and with their environment, and how they respond to natural disturbances (*e.g.* changes in fluid flow, lava flows and seismic events).

Mineral exploitation

Currently 99% of extracted minerals come from the 29% of the world that is land. Reserves of many metals, such as copper, are being depleted at a greater rate than new reserves are being discovered and mining companies are now investigating the possibility of mining marine metal sulphide deposits, including chalcopyrite ($CuFeS_2$), which have been formed at hydrothermal vents. Scott[2] provided the following overview of the current situation. Marine technology has now improved to a stage at which engineers are confident that mining machines can be constructed to work at several thousand metres of water depth. There are some apparent environmental advantages to mining on the seabed; for example there will be no acid mine drainage. There may be cost advantages; a large mining ship or barge is mobile and could be moved from one ore deposit to another. This mobility is not a feature of most current onshore methods. In addition, the legal problems of tenure may be fewer and less complex than those on land.

Even with these trends, it is difficult to predict the timing of potential future exploitation at vent sites. The timing will depend upon economic conditions favouring marine mineral development in the face of mineral conservation, recycling, substitution, technological advances in onshore mining, exploration in other areas, and declining price trends in most metal markets. Nautilus Mineral Corporation license has been extended to 2003 by the Papua New Guinea government, for the exploration of polymetallic sulphide deposits at all hydrothermal sites in the East Manus Basin. Neptune Resources has applied to the New Zealand government for an exploration license in the Havre Trough. Neptune has recently merged with Deep Sea Minerals, which has 3 further applications pending for exploration licences. Other sites of potential interest are the Okinawa Trough, the Bonin area, the Atlantis II Deep, Middle Valley and the Explorer Ridge. The majority of sites of initial mining interest are likely to be in Back Arc areas. Mining is likely to occur first within EEZs, because under the Law of the Sea Convention, regulations for claims and exploitation in “the Area” (the seabed lying beyond the limits of national jurisdiction) are not yet in place. The International Seabed Authority has drawn up regulations for claims to recover manganese nodules. A workshop to consider regulations for polymetallic sulphides was sponsored by the International Seabed Authority in June 2000. Canada is currently developing a policy for offshore mineral extraction within the Canadian EEZ.

<u>Environmental effects of mining hydrothermal vent sites</u> - Mining activities in the future are likely to be concentrated in geographically limited areas where polymetallic sulphide deposits of commercial size are known to occur[2]. Extraction of the ore deposits will result in the selective removal of the substratum and the production of a particulate plume. Some organisms will be killed directly by mining machinery, while others may face the risk of smothering by material settling out from the particulate plume. Individual organisms that survive these perturbations will be subject to a radical change in habitat conditions; hard substrata will be replaced by soft particulates that settle out from the mining plume. These particulates may also clog hydrothermal conduits, depriving established vent communities of their fluid supply. Removal of sections of the sulphide deposits may change the subsurface hydrology beneath the vent openings, possibly decreasing or stopping hydrothermal fluid flow to remaining vents. At sedimented hydrothermal sites, where much of the ore body lies within a sediment overburden, digging out the deposit would produce a much more extensive plume that could completely eradicate the local vent fauna. Experiments on the effect of sulphide particle discharge on vent species may be needed in order to allow an estimate of environmental damage.

Some large seafloor polymetallic sulphide deposits are hydrothermally inactive and provide no habitat for a specialised vent fauna. Anecdotal observations at inactive deposits have noted colonisation by 'normal' deep-sea organisms. Such observations suggest that mining would pose little threat to the survival of individual species because the fauna has been drawn from the surrounding deep sea. This requires verification. Inactive vent sites have received little attention from biologists, and more extensive sampling will be required to establish the nature of their fauna. Mining would effectively eliminate the habitat formed by inactive deposits, so it is important to confirm that they host only background deep-sea species.

At present, it is not possible to predict how rapidly sites may recover from mining operations. This will depend in part on the extent to which local populations of hydrothermal vent species have been destroyed and on whether there are other populations within larval recruitment range to allow recolonisation of suitable sites. It is important to realise that those long-lived vent fields that host the largest mineral deposits are likely to exhibit the greatest ecological stability and biodiversity. These fields may be important regional sites of species origin and dispersal.

Effects of land mining on submarine hydrothermal sites - Mining occurs on several islands and mine tailings are sometimes discharged into the sea for disposal. These discharges occur, for example, off New Ireland, Papua New Guinea and Misima Is. in the Solomon Sea. Currently the discharge of mine tailings is not known to affect hydrothermal sites.

Geothermal Exploitation

Hydrothermal reservoirs are used in many countries as a source of heat for geothermal power stations, local heating of buildings and glass houses, and for spa baths. Large-scale heat or hydrothermal fluid extraction could reduce the flow of hydrothermal fluid to natural outlets, including those supporting vent organisms. This type of extraction may be regarded as leading to a premature ageing of vent sites, rather than to the more rapid elimination of habitat, which could be caused by mining.

Tourism

Tourist use of submarine hydrothermal vent sites is a minor use on a global scale but may increase substantially. Russia has taken tourists to the Rainbow vent site on the Mid-Atlantic Ridge in Mir submersibles, and diving tourists regularly visit some of the Italian caves with geothermal springs as well as the top of the Dom João de Castro Seamount in the Açores. SCUBA-diving tourists (and diving scientists) may damage the cave ecosystems through the release of exhaust air. The air forms gas pockets under the roof of the cave, killing the bacterial mats, on which much of the cave ecosystem depends, by cutting off their access to the seawater. Disturbance of scientific experiments by tourists or fishermen is a common problem in coastal oceanography, preventing serious experimentation and long-term observation at several popular inshore sites such as Vulcano and Santorini.

Virtual tourism should be encouraged as well as the highly successful "teacher at sea programmes". Perhaps the Russian example of mixing tourism and science could be developed by other nations.

Bioprospecting

Hydrothermal vents are colonised by hyperthermophilic Bacteria and Archaea. Enzymes from these organisms may have a range of applications from molecular biology to food processing, and in the fabric, and chemical industries. The "Taq" DNA polymerase enzyme, used worldwide in molecular biology, is produced from *Thermus aquaticus*, a thermophile first isolated from terrestrial hot springs. Today, the annual market for Taq polymerase is estimated at approximately $500 million per year. Several DNA polymerase enzymes from hydrothermal organisms are presently being marketed, including a "Vent polymerase" extracted from an organism first collected at shallow hydrothermal vents off Vulcano, Italy. We still know very little about the biodiversity of microbes at vents. As a result, their full biotechnological potential remains unquantifiable. There are a strong economic and ecological arguments for preserving vent sites to safeguard this biodiversity and the genetic potential of both the prokaryotic and higher organisms.

Several countries have established public policies and agencies responsible for managing the exploitation of their natural biodiversity resources and issuing bioprospecting permits. For example, INBio manages the biodiversity resources in Costa Rica: Yellowstone National Park now issues permits for collecting and has implemented an exploitation agreement with scientists collecting samples: BioNet of Papua New Guinea had an observer onboard for the just concluded ODP Leg 193 in Manus Basin and will have a say in all future cruises in the area.

Although microbial sampling for bioprospecting or basic microbiological research usually causes less habitat destruction than much other sampling, the ecological impact of redistributing micro-organisms between sites remains to be evaluated.

Threat Management

Acceptable level of reduction of biodiversity or habitat integrity must be defined on a case by case basis. Population and spatial scales as well as life history characteristics (*e.g.* generation times) and ecological dynamics (*i.e.* sampling may affect the outcome of inter-species competition) need to be considered. The aim should be for "sustainable use", *i.e.* use of the components of biological diversity in a way, and at a rate, which does not lead to the long-term decline in diversity.

An Environmental Impact Assessment (EIA) would provide an objective and recognised basis for developing a management plan for vent sites or for deciding on the need for management or restricted access. The International Marine Minerals Society is drafting a code of conduct for environmental assessment in potential marine mining areas. Workshop participants agreed that an EIA would be in keeping with standard practice in environmental management elsewhere, but the question was not discussed at length. Any EIA undertaken in relation to new initiatives at hydrothermal vent sites should include standard criteria used in EIA in other marine habitats, such as:

1) Characterisation of the type of disturbance - in particular the destruction of the substratum and associated organisms. In the case of mining activities, this characterisation would include a description of the particulate plumes that could bury or stress organisms in adjacent areas.

2) Estimation of the percent loss of seafloor vent habitats - most vent fields include several types of habitat that host different assemblages of organisms. These habitats and their faunas remain poorly characterized. Managing the impact of scientific, tourism, or mining on individual species will first require information on the nature of these habitats and the species found within them. Only then will it be possible to make management decisions based on estimates of disturbance (fraction of individual types of habitat that would remain undisturbed, and total disturbance).

3) Identification of affected seafloor organisms - this information is critical to evaluating the impact of various human activities on the survival of species. Species with a broad geographic range are less likely to be endangered by localised disturbances. On the other hand, sites containing species with restricted distribution will require more careful management to assure maintenance of biodiversity.

4) Dose-response characteristics of plume fallout - many vent species are sessile or capable of only limited locomotion. Some feed by filtering particles from surrounding seawater. In both cases, the presence of particulate plumes or sediment fallout from mining could have adverse affects on their survival, even if they are not directly disturbed by mineral extraction machinery. There is no published information on the dose-response characteristics of vent organisms in relation to particulate plumes.

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Criteria for Identifying Critical or Sensitive Sites

There is no imminent threat to the global vent fauna from science, tourism, mining or any other human activity. Future concentration of activities at certain sites could, however, produce local and even regional effects on biological processes and organism abundance to the point where the scientific value of the site could be compromised and, eventually, the survival of some species could become an issue. Workshop participants agreed that management or protection of all of the world's marine hydrothermal sites was an unrealistic goal. Discussions focused instead on the criteria for identifying sites that are of critical importance, or particularly sensitive to disturbance, because of their scientific value or their significance for species survival. These criteria are presented below as a series of questions that may be asked when considering the need for management or restriction of human activities in a vent field. An assessment of the anticipated level of perturbation, and the feasibility of management of the sites also has to be considered. The questions are listed under three headings; the first two of these employ terminology from the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Biodiversity (CBD).

"Threatened and Endangered Species"

Is there a high degree of endemism?
A species that is endemic to a particular vent field could be perceived as threatened or endangered if its habitat was to be disturbed by intensive scientific activity, tourism or industrial exploitation. Given the present very incomplete sampling of vent sites worldwide, it would be difficult to argue for adoption of conservation measures based on the occurrence of a single species known today only from one site. However, some vent fields and regions are already known to have a high degree of endemism (*i.e.* many endemic species), possibly as a result of geographic isolation or unique habitat conditions. A perceived threat or endangerment to a group of endemic species would argue more strongly for development of a management plan.

Are there unique species present?
Many vent faunal species exhibit unusual symbioses and physiological adaptations, or show primitive characteristics and could be classed as evolutionary relics. Some vent fields contain species that are both endemic and carry unique biological or evolutionary traits. This property of uniqueness increases the value of the species to science and society and could be considered as an additional argument for taking measures to avoid species extinction.

Do the affected species have restricted geographic distribution or recruitment potential?
This question pertains to the ability of species to recolonise a site following a disturbance. It is likely to be most relevant in cases where the global survival of one or more species is not at issue (*i.e.* they are found elsewhere) but the situation is such that disturbance may threaten or endanger the local or regional survival of species. This could significantly diminish the global genetic diversity of the affected species as well as the local or regional species biodiversity.

"Rare and Fragile Ecosystems"

In addition to harbouring endemic and possibly unique species, a vent site could also be considered critically important or sensitive to disturbance because of more general, ecosystem-level properties. In other words, the site could be viewed as a 'rare and fragile ecosystem', as provided for in various regulatory documents. Some examples of critical or sensitive ecosystem-level questions that apply specifically to marine hydrothermal vents are:

Is the site unusually long-lived?
Because of the dynamic geological setting within which they occur, hydrothermal vents and vent fields tend to be relatively short-lived, compared to other seafloor habitats. As a consequence, long-lived hydrothermal sites are indeed rare ecosystems. There is some evidence that biodiversity within a given region is greatest at larger, longer-lived hydrothermal sites[1,2]. This is in keeping with what has been observed in other ecosystems on Earth. Long-lived 'mother populations' may be critical to the maintenance of vent species biodiversity within a region. These same long-lived hydrothermal sites are also the most likely locations for accumulation of large sulphide deposits and therefore will be prime targets for mining.

Is there high species and/or genetic diversity?
A vent field may be considered rare, or possibly even fragile, because of high species diversity, as defined by different diversity indices. The high diversity (compared to other vent sites) could be the result of a unique biogeographical situation, unusual habitat diversity or exceptional historic stability. Even where all species present may individually occur elsewhere, a situation of unusual species diversity implies a greater complexity of interactions within the ecosystem. Ecologists are still debating whether or not this makes an ecosystem more or less vulnerable to disturbance (*i.e.* 'fragile'). Unusually diverse and complex vent ecosystems can be considered as 'rare', and their complexity, or rarity, would be diminished by loss of more common species. At least some shallow water coastal hydrothermal sites exhibit a high epifaunal species diversity compared to surrounding areas[3] and could act as refugia for species during adverse conditions in the coastal zone. Mathematical diversity indices provide an objective means of ranking the species diversity of different sites.

In addition to species diversity, the discussions briefly considered whether or not genetic diversity within populations could also be considered as a site-specific or ecosystem level attribute. Considering their accessibility and recent discovery, vent organisms have been the subject of an unusual number of studies of gene flow and genetic diversity within populations. It is now possible to identify sites that have exceptionally diverse populations. However, it was pointed out that studies are still too incomplete or dispersed to permit any meaningful ranking of vent sites according to the genetic diversity of even their most common species.

Is there unusually high environmental diversity?
An exceptional diversity of habitat in a vent field will favour higher species diversity. In addition, it can create assemblages of species not seen elsewhere, because of the juxtaposition of different habitats. This could create unusual trophic and other ecological interactions, resulting in a 'rare' ecosystem. One example is the particular situation of vent habitats within the photic zone where both plants and chemosynthetic microbes can serve as food sources.

Are there unique ecological interactions?
Hydrothermal vents are already known as sites of unusual interactions between prokaryotes and macrofauna and geological and geochemical features. Nonetheless there are sites where special circumstances create truly unique interactions between organisms and environment. Examples include the diverse and abundant bacterial mat growth on the hydrocarbon rich sediments of the Guaymas Basin vents (Gulf of California) and the exceptional development of hydrothermal edifices and the edifice fauna at the Endeavour Segment vents (Juan de Fuca Ridge, northeast Pacific).

Other Criteria

Is the site of exceptional scientific value?
The scientific value of a hydrothermal vent site will, in part, be determined by many of the points considered above. In addition, such properties as recent geological history or frequency of natural perturbation are of interest to researchers studying long-term ecosystem processes. Vent fields at 9°N on the East Pacific Rise (EPR) and Axial Volcano (Juan de Fuca Ridge) have become sites for time-series studies of post-eruptive colonisation and ecosystem development. Other sites may have hydrological,

geological or geochemical properties that give them exceptional scientific value. These latter properties could be significantly changed by major interventions such as seabed mining or subseafloor drilling. Finally, the geographic proximity of a site to research institutions also has a bearing on its scientific value. The reality of funding and staging oceanographic expeditions, or positioning remote observatories, means that intensive and sustained research efforts are most likely to take place at sites closest to major institutions or states with significant research resources. As a result, frequently visited and intensively studied sites become more and more valuable to science as knowledge of their properties accrues. As we learn more about the basic features of a site, we can begin to ask higher order questions.

Is the site particularly valuable for education?
The remote and extreme nature of the deep-sea hydrothermal environment, together with visually spectacular black smokers and dense animal populations, have made hot vents popular with the general public. Many researchers and science educators are taking advantage of this popularity to teach the public about basic biology, ecology, and earth processes such a plate tectonics, volcanism and mineral deposit formation. For the present, educational activities are mostly following the science, in terms of determining what sites and information will be featured in written, film or multi-media products. Some sites, because of their visual nature, access and geological and biological properties are more suitable than others for public education. It is not unreasonable to expect that the educational value should be considered, together with the intrinsic properties of a vent field, in considerations of the need to manage human activities at a vent site.

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Current and Proposed Marine Reserves, Protected Areas and Management Plans for Specific Hydrothermal Areas

The Endeavour Hydrothermal Vents Marine Protected Area

The Canadian Oceans Act of 1997 allowed the introduction of integrated management plans for areas within the EEZ. Two pilot offshore marine protected areas (MPAs) were announced in December 1998: the Bowie Seamount (to conserve and protect the ecosystem and habitat associated with Bowie Seamount) and the Endeavour Segment of the Juan de Fuca Ridge (the largest and most diverse of several hydrothermal sites on the ridge). These offshore MPAs are part of an initiative by the Canadian government to develop a national system of Marine Protected Areas.

The action plan for The Endeavour Hydrothermal Vents Marine Protected Area involved: identifying stakeholders (mining industry, academic researchers, educators etc.), developing an ecosystem overview, and establishing a planning and advisory team to develop recommendations. The MPA lies within the boundaries of the box defined by 48° 01'N to 47° 54' N and 128° 08' W to 129° 02' W. It includes (from South to North) the Mothra, Main Endeavour, High Rise and Salty Dawg vent fields. The MPA will include the overlying water column and the sub-seafloor. A management committee for the MPA is being formed, and the management plan is under development. Current information on the Canadian government initiatives, including MPAs can be found at the following web sites :
Ocean Program Activity Tracking (OPAT) : http://www.dfo-mpo.gc.ca/CanOceans/INDEX.HTM
Ocean Conservation : http://www.oceansconservation.com
Pacific MPA projects: http://www.pac.dfo-mpo.gc.ca/oceans/mpa/pilots.htm

Kraternaya Bight, Yankich Island in the Kuriles

This sunken caldera, open to the sea, was made a Biological Reserve in 1988 by the Sakhalin District Council, following several years of studies by Russian scientists[1] on the unusual ecosystem surrounding submarine hydrothermal vents in the flooded crater. Much of the fauna is not found in nearby coastal sites.

Dom João de Castro Seamount in the Açores

This seamount, between the islands of São Miguel and Terceira, was briefly an island, following an eruption in 1720, and currently rises from a depth of 1000 m to within 13 m of the surface. It has hydrothermal venting from the sunken caldera at 30-50 m depth and also from sites on the flanks. In 1998 the seamount was made a Special Area for Conservation and a Site of European Community Importance (Resolution no. 30/98 of 5 Feb. and Declaration no. 12/98 of May 7th) by the Portuguese Government in conformity with the 1992 EC Habitat Directive. The seamount has recently been a target for a demonstration project to use an autonomous underwater vehicle (AUV) to locate vents and follow changes in vent activity, see
http://joel.ist.utl.pt/dsor/Projects/Asimov/.

Other Proposed Reserves and Protected Areas

Italy has a number of marine reserves under the 979/82 act for Preservation of the Sea and is proposing a large number of new reserves including one covering the Aeolian Islands in the Tyrrhenian Sea. The islands contain several well-studied hydrothermal sites including those off Vulcano and Panarea[2]. The second Italian National Convention on Marine Science was held in Genova in November 2000. One of the three topics of the meeting was marine protected areas.

Potential Reserves and Protected Areas

The World Wildlife Fund (WWF) has proposed a potential Marine Protected Area at Lucky Strike, on the Mid-Atlantic Ridge, within the Portuguese EEZ, under OSPAR (the Convention for the Protection of the Marine Environment of the North-East Atlantic). Annex V of OSPAR contains provisos with regard to the protection and conservation of the ecosystems and biological diversity of the maritime area. One of the four main areas for the future work of OSPAR is the "protection and conservation of ecosystems and habitat diversity".

The potential for MPAs in international waters was a subject for discussion at the Asian Pacific Economic Conference in Vancouver in December 2000. Further discussion of the scientific requirements and legal aspects of high seas marine protected areas were discussed at a workshop sponsored the German Federal Agency for Nature Conservation, held on the Isle of Vilm, Germany, 27 February to 4 March 2001.

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Establishing the Legal Basis to Conserve and Sustainably Use Hydrothermal Vents and Their Biological Communities*

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Hydrothermal vents are widespread, but the vast majority have yet to be discovered and explored. Those that are known and most accessible will be increasingly threatened by human activities, namely seabed mining, marine scientific research, biological sampling, and bioprospecting. The following is a brief survey of the threats to hydrothermal vents and how the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Biological Diversity (CBD) may apply.

Seabed Mining

Mining for polymetallic sulphide deposits poses the greatest potential physical threat to hydrothermal vents and their biological communities. Mining in areas of national jurisdiction, where vents with potentially valuable associated minerals lie close to shore, is the most immediate threat. The best example is the plans of a mining consortium to explore the feasibility of mining polymetallic sulphide deposits from a vent system located in the Manus Basin of the Bismarck Sea[1]. The site is located within the Exclusive Economic Zone (EEZ) of Papua New Guinea. Papua New Guinea is a Contracting Party to UNCLOS and the CBD[2].

The international legal basis to conserve and sustainably use hydrothermal vent areas within areas of national jurisdiction is fairly clear and national environmental regulatory processes may already exist. As a principle of international environmental law, a state has the sovereign right to exploit its natural resources provided it does not damage the environment of other states and areas beyond national jurisdiction. The extent to which it must account for the environmental impacts of actions within its own territory depends on its other international environmental obligations and its domestic national environmental laws.

As Contracting Parties to UNCLOS, Papua New Guinea and other countries have the very general obligations to: (1) "protect and preserve the marine environment" and (2) "protect and preserve rare or fragile ecosystems"[3]. Contracting Parties to the CBD have a range of explicit obligations to conserve biological diversity and use its components sustainably. In order to ensure fulfilment of these obligations, countries should: (1) identify any biological communities associated with the target vent system and (2) regulate or manage the activity to eliminate or minimize impacts on biodiversity. Therefore, an environmental impact assessment should be required.

In addition, public participation should be allowed in the regulatory oversight and environmental impact assessment processes. This would allow marine scientific researchers to offer the best available information on the particular sites under review to help determine what the proposal's potential impacts would be. They might also be able to steer proposed activities away from rare or fragile sites or those of particular scientific interest. One example of this procedure occurred in relation to scientific drilling by the Ocean Drilling Program at a hydrothermal site within the Canadian EEZ. A federally-required EIA was conducted prior to drilling operations, which included submersible dives, habitat mapping and

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biological sampling[4]. The EIA identified several sensitive habitat areas, which were subsequently avoided during drilling operations.

In the Area (that portion of the seabed lying beyond the limits of national jurisdiction) polymetallic sulphide deposits are part of the common heritage of humankind[5a]. In effect, they are international property. The right to explore and exploit them rests solely with the international community[5b]. Like polymetallic nodules, the deposits are not currently economically exploitable. They will be more expensive to recover and process than resources currently available on land. As a result, it is unclear when such mining will actually occur.

Pursuant to UNCLOS, the International Seabed Authority (ISA) needs to develop a mining code for sulphide deposits before any mining takes place. In 1998, the Russian delegation to the ISA proposed an initiative to establish this code[6]. Unfortunately, it is still too early to determine the scope of the code. It may be similar to the draft code for manganese nodule mining that the ISA has been working on for a number of years.

The forthcoming ISA polymetallic sulphide deposits code should include strong environmental impact assessment procedures. These procedures are not well developed in the draft nodule code. This would help to fulfil the stipulation in UNCLOS that the codes protect and conserve the Area's natural resources and prevent damage to the flora and fauna of the marine environment[7]. The intergovernmental process to develop such a code would surely benefit from and could be influenced by available marine scientific research.

Marine Scientific Research

The most immediate threat to hydrothermal vent systems and their associated biological communities is marine scientific research. As a "use," marine scientific research needs to be sustainable just like any other natural resource-based activity. The CBD defines "sustainable use" as using the "components of biological diversity in a way and at a rate that does not lead to the long term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of future generations."[8]. This definition recognizes that biological diversity conservation cannot be separated from the sustainable use of its components: genomes, populations of species, and ecosystems. In other words, to conserve biological diversity, its tangible manifestations must be conserved and sustainably used[9]. Commentators have noted that one aspect of the threat posed by marine scientific research originates from a shift in research priorities from exploration and discovery to those emphasizing temporal processes[10]. Consequently, the "concentration of sampling, observation and instrumentation at a small number of well known hydrothermal sites" has led to the realisation "that certain activities are incompatible, and that even more co-operation and co-ordination will be required to resolve potential conflict."[10].

The main problem is a conflict between observational and monitoring activities that are compromised by disturbance and those activities that involve manipulating or collecting biological or geological samples from a particular area. Commentators have asserted that "disturbance by researchers can have a substantial impact on vent systems" and that "anthropogenic changes in distribution and occurrence of vent fluid flows and of associated vent communities have been well documented at vents along the East Pacific Rise, on the Juan de Fuca Ridge and at the TAG field on the Mid-Atlantic Ridge."[10].

In areas of national jurisdiction, managing physical access to sites of scientific interest or of importance for biodiversity conservation may be a viable solution. At a minimum, the overseeing agency for marine scientific research within a coastal state's EEZ and on the continental shelf could provide a screening or clearing-house type function.

When a vessel clearance or permit application to undertake research is first received, the agency could identify potential conflicts and make prospective researchers aware of them before they occur. If the state is particularly advanced, granting permission to undertake activities in an area might be informed by a management plan and an environmental impact assessment, particularly if the location has already been established as a protected area. This seems to be the approach that Canada will ultimately take with regard to the Endeavour Hydrothermal Vents site, presently designated as a "pilot marine protected area", located on the Juan de Fuca Ridge within Canada's EEZ[11]. Canada has not ratified UNCLOS and thus is not a Contracting Party that must implement the treaty's obligations. The Endeavour proposal would be a step towards implementing the spirit of the UNCLOS provisions to protect and preserve the marine environment and to protect rare and fragile ecosystems. It would also be a step towards implementing the various conservation obligations Canada has accepted as a Contracting Party to the CBD.

In this or other areas, zoning a vent system according to the UNESCO Biosphere Reserve approach could be envisioned. Although currently this approach is limited to terrestrial use, UNESCO is exploring how the concept can be applied to marine areas[12]. Zoning entails delineating an area into zones to be managed to achieve particular objectives. These objectives might include: (1) a core area or areas devoted to strict protection where the possibility might exist for non-invasive observational research, (2) a delineated buffer zone where only research and other activities compatible with specified objectives could take place. In some situations, there could be a transition zone where more invasive activities such as seabed mining could take place.

Such an approach would certainly be in keeping with the general UNCLOS provisions on protecting and preserving the marine environment and protecting fragile or unique ecosystems. Proper zonation would also support the CBD objectives to conserve biodiversity and sustainably use its components by identifying and managing threats to biodiversity and creating protected areas[13].

As one might imagine, the situation is considerably less structured in areas beyond the limits of national jurisdiction. At this time there is no agency with a mandate to oversee marine scientific research activities or biological resources on the seabed.

The ISA's mandate is limited to the seabed's mineral resources[14]. ISA addresses marine scientific research and the seabed's biological communities only when seabed mining is involved[14]. Without (1) direct measures taken by researching states to regulate the conduct of their marine scientific researchers in the Area, (2) a new international treaty, or (3) voluntary oversight by the scientific community itself, there is very little that UNCLOS or the CBD can directly offer at present to minimise the potential use conflicts and threats that marine scientific research may pose to a hydrothermal system. Although a new international treaty is unlikely, direct measures by an individual or a group of researching states are possible, especially pursuant to treaty obligations under UNCLOS and the CBD.

The outstanding problem is motivating states to act in the first place. A related problem may involve co-ordinating and harmonising disparate approaches that states may take if they act individually. Both these issues could be taken up by UNESCO's Intergovernmental Oceanographic Commission (IOC) whose mandate, among other things, includes marine scientific research. Intergovernmental processes, however, tend to be time consuming and slow.

Voluntary approaches, such as self-policing, initiated by marine scientific researchers, may be the most expeditious way to minimise the conflicts and environmental impacts marine scientific research activities may pose. While such voluntary actions have been proposed,[10] co-ordination and collaboration between marine scientific researchers would be required for success. A co-ordinating body, such as a consortium of developed and developing states undertaking research on hydrothermal vents, would be needed. It might be possible for InterRidge to fulfil such a role.

A step towards voluntary action is already being taken as a result of a 1995 recommendation by the InterRidge Biological Studies Ad Hoc Committee to demarcate "seabed sanctuaries."[15]. This was subsequently elaborated further in a position paper, which proposed a "research reserve system regulated entirely by consensus."[10]. It was proposed that InterRidge would disseminate information and summarise controversies. Researchers would be encouraged to devote dive time to explore new sites to alleviate collecting pressure at the most popular sites. Thus far, two sites in the Area have been proposed, one on the East Pacific Rise, the other on the Mid-Atlantic Ridge.

Without state action, voluntary actions by marine researchers would support the spirit of UNCLOS since it applies to marine scientific research beyond the areas of national jurisdiction. On the high seas and in the Area, all states and competent international organizations have the right to conduct marine scientific research[16]. Unlike the high seas, all marine scientific research within the Area "shall be carried out for the benefit of [hu]mankind as a whole - -"[17]. Unfortunately, UNCLOS defines neither "marine scientific research" nor "benefit of [hu]mankind as a whole."

Arguably, the scientific community's voluntary actions would contribute to the conservation and sustainable use of hydrothermal vents and their associated biodiversity, thereby benefiting humankind as a whole. This also would support the spirit of the CBD's international co-operation provisions and its declaration that biodiversity conservation is a "common concern of humankind."[18].

With any voluntary system the participants must know the principles upon which it is based. In lieu of regulatory oversight, the scientific community could undertake to develop a professional code of conduct for activities involving hydrothermal vents to guide researchers. The code could provide a reference point against which they could judge their own conduct and the conduct of their peers.

Furthermore, the ultimate success of any voluntary system or instrument, such as a professional code of conduct, is intimately related to the process by which it is developed. It is a well-established principle in modern conservation circles that the key stakeholders must be involved in any process whose result may have an impact upon their activities.

Incentives may need to be provided to encourage compliance. For example, national funding institutions could agree to conditionally grant money upon the demonstrable application of the code of conduct by the grantee. Peer pressure may also play a role in the ultimate success of any voluntary system. To fully ensure the code's application, and to give it added weight, it may need to be solidified further by an intergovernmental body such as the UNESCO IOC. This would ensure oversight of its implementation at the global level and may encourage its voluntary application by states.

Biological Sampling

Biological sampling of macro- and micro-organisms is a primary methodological tool of many marine scientific research activities both within and beyond the limits of national jurisdiction. Depending on the circumstances, sampling activities may put pressure on hydrothermal biological communities causing adverse impacts. Consequently, sampling may not be sustainable at some locations, especially sampling involving metazoans. Direct impacts associated with sampling a limited population of organisms are clearly possible. Possible indirect impacts are less discernible. For example, sampling in unique environments may be an unsustainable use, without precautions to minimise the introduction of alien species from one site to another. For such reasons, in areas of national jurisdiction, there are clear intersections between these activities, the UNCLOS provision on rare and fragile ecosystems previously described, and the CBD's sustainable use provisions.

As with seabed mining, a CBD Contracting Party is to identify actual or potential threats to biodiversity, and thereafter regulate or manage them to minimise those threats[19]. A complementary provision requires the coastal state to adopt measures relating to the use of biological resources to avoid or minimise adverse impacts on biological diversity[20]. Intersections with environmental impact assessment are apparent[21]. Finally, a Contracting Party is required to regulate and manage the collection of biological resources from natural habitats for ex-*situ* conservation purposes so as not to threaten ecosystems and *in situ* populations of species[22].

Beyond national jurisdiction, the situation is similar to that for general marine scientific research. Under UNCLOS, unsustainable collecting for research purposes could be interpreted as inconsistent with the requirement that marine scientific research is to be undertaken for the benefit of humankind as a whole. As suggested above, voluntary action by the marine scientific research community could suffice in the absence of a new treaty or until other state action takes place.

In 1995, the InterRidge Biological Studies Ad Hoc Committee recommended that the Member States of InterRidge establish a voluntary international specimen or sample exchange agreement whose "aim is to avoid duplication of sampling which is costly not only in monetary terms but also in terms of environmental impact"[15]. The idea was further elaborated by a group of scientists in 1997 at the First International Hydrothermal Vent Biology Symposium in Madeira, Portugal.

The exchange agreement would augment existing international specimen exchanges. Support would be provided by an internet-based database with information on existing biological samples. In addition, non-biological research cruises would be provided with "bio-boxes" for collecting and preserving biological samples and making them available for exchange.

The draft agreement has yet to be officially endorsed by InterRidge Member States. National corresponding curators have been asked to draw on its terms and conditions, including its prohibitions on redistributing exchanged samples and using the samples for commercially-oriented research. The initiative would contribute to one aspect of the sustainable use of vent organisms.

Bioprospecting

Marine scientific research activities, particularly those related to biological and geological sampling, are becoming increasingly linked to onshore commercial bioprospecting activities [23]. The true extent of marine bioprospecting at hydrothermal vent sites within and beyond areas of national jurisdiction is unknown. However, these activities probably do not pose an immediate threat to biological communities associated with hydrothermal vents, with the possible exception of the risk of redistribution of endemic micro-organisms between vent sites. At present, there is no scientific basis to suggest that endemic microbial populations exist at any hydrothermal vent site.

Sustainability may need to be considered where bioprospectors need large quantities of a macro-organism to obtain useful quantities of a secondary metabolite produced by, for example, a mutualistic micro-organism. If the secondary metabolite is not readily synthesizable and the micro-organism is not culturable, then harvesting the macro-organism at unsustainable levels could threaten both the micro-organism, as well as the particular ecosystem[24].

Beyond environmental impacts, biological sampling at hydrothermal vents within the limits of national jurisdiction may have implications for marine scientific researchers and bioprospectors. There may be a need to seek prior informed consent and negotiate mutually agreed terms and ultimately share benefits for the use of genetic resources.

The CBD's genetic resources provisions apply only to marine areas within the areas of national jurisdiction[25]. These provisions require marine scientific researchers and bioprospectors to obtain the government's prior informed consent before accessing the area[25]. Prior informed consent will be subject to mutually agreed upon terms, including benefit sharing. Similarly, within the limits of national jurisdiction, UNCLOS requires that consent first be acquired for marine scientific research[26].

Under UNCLOS, consent is presumed unless the coastal state has reason to be believe the proposed research is "directly significant" to commercial exploration and exploitation of natural resources, whether living or nonliving[27]. Where the marine scientific research is for non-commercial purposes, the researching state is to: (1) enable the participation of the scientists from the coastal state, (2) provide preliminary reports and final results upon request, (3) provide access to samples and data collected upon request, (4) provide sample and data assessment, and (5) research results upon request; and ensure international availability of the research results[28].

Beyond the limits of national jurisdiction, the CBD's provisions on genetic resources access and benefit sharing are not applicable[29]. Nevertheless, the CBD COP has called upon the CBD Secretariat to study the conservation and sustainable use of deep seabed genetic resources in relation to bioprospecting[30]. The U.N. Secretary General has highlighted the importance of the CBD study[31]. The Independent World Commission on Oceans has also called for a study[32].

Even though UNCLOS and the CBD do not squarely address hydrothermal vents, they can still be used as the international legal basis to ensure conservation and sustainable use. The clearest applications exist in areas of national jurisdiction. The CBD study of seabed genetic resources could provide leverage for a wider treatment of other deep seabed biodiversity issues, including those associated with hydrothermal vents.

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[3] UNCLOS, arts. 192, 194(5). The general obligation to protect and preserve rare or fragile ecosystems under Article 194(5) appears in a section entitled: "Measures to prevent, reduce and control pollution of the marine environment." Id. The intent is to ensure that UNCLOS Contracting Parties take into consideration the protection of rare or fragile ecosystems when they take measures to prevent, reduce, and control pollution. id. There is some difficulty reading this as a stand alone obligation to protect rare or fragile ecosystems for reasons other than pollution prevention, reduction, and control. Notwithstanding this limitation, the CBD can be interpreted to provide a gap-filling function when a state is a party to both instruments.

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[5b] UNCLOS. pt. XI, § 2, art. 137.

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[25] CBD, art. 15.

[26] UNCLOS, art. 246(2).

[27] UNCLOS. arts. 246(3), (5)(a).

[28] UNCLOS. art. 249.

[29] CBD, art. 4(a).

[30] Report of the Second Meeting of the COP, at 60, para. 12. In 1995, the CBD COP directed the CBD Secretariat as follows:

[I]n consultation with the United Nations Office for Ocean Affairs and the Law of the Sea, . . . undertake a study of the relationship between the Convention on Biological Diversity and the United Nations Convention on the Law of the Sea with regard to the conservation and sustainable use of genetic resources on the deep seabed.

This would "[enable] the [SBSTTA] to address, at future meetings, the scientific, technical and technological issues related to bio-prospecting of genetic resources on the deep seabed."

As of December 1999, the study has yet to be undertaken. For a general overview of the issue see Glowka, L. Genetic Resources, Marine Scientific Research and the International Seabed Area, in 8 Review of European Community and International Environmental Law 56 (1999); and Glowka, L. The Deepest of Ironies: Genetic Resources, Marine Scientific Research, and the Area, 12 Ocean Y.B. 154 (1996).

[31] The general subject of marine and coastal biodiversity, as well as the specific issue of access to the genetic resources of the deep seabed, raise important questions. The topic touches not only on the protection and preservation of the marine environment, including that of the international seabed area, but also on such other matters as the application of the consent regime for marine scientific research, . . . the duties of conservation and management of the living resources of the high seas, and the sustainable development of living marine resources generally. The specific issue of access points to the need for the rational and orderly development of activities relating to the utilization of genetic resources derived from the deep seabed area beyond the limits of national jurisdiction. The study to be prepared for Parties to the Biodiversity Convention will be of equal, or possibly greater importance to States Parties to the United Nations Convention on the Law of the Sea, as well as Member States in the General Assembly . . . . Law of the Sea: Report of the Secretary General, U.N. General Assembly, 51st Sess., Agenda Item 24(a), at 59, U.N. Doc. A/51/645 (1996).

[32] The Ocean Our Future, The Report of the Independent World Commission on the Oceans (1998). "The potentials of the genetic resources of the seabed should become the subject of urgent study, focusing on their legal, environmental and economic implications, and negotiation leading to their inclusion within an appropriate international regulatory regime."

Managing Scientific Activities

In the foreseeable future, the management of research activities at hydrothermal vents will be voluntary, with the exception of formal regulation within areas of national jurisdiction. Successful voluntary management will require mechanisms that facilitate communication and encourage participation at all levels, from individual users to national programmes. Working groups discussed several options for improved communication and community participation:

Communication

Hydrothermal vent research, throughout the oceans of the world, is conducted by diverse individual scientists and national programmes. No single agency is responsible for funding or governing all of this research activity, nor is there any common forum for disseminating information relevant to the management of individual vent sites. The establishment of a central clearing-house for information about research plans was identified an important early priority for management and conservation. The InterRidge Office, which, through its membership and infrastructure, is able to reach most of the world's ridge scientists, was seen as the most likely candidate for this role. In addition to communicating with individual scientists, the InterRidge office would communicate regularly with national mid-ocean ridge research programs, research vessel operators (UNOLS, NOAA, GENAVIR, SOC, DFO) and, eventually, management committees of any vent sites given Marine Protected Area status. Effective voluntary management will require that agencies and individual scientists communicate regularly with the InterRidge Office (or other designated clearing-house), to consult and update the central data base prior to considering or initiating new research activities. The promotion of ridge crest research through international co-operation is one of the founding principles of InterRidge, which could take on the task of creating and maintaining a voluntary management database without the need for substantial new resources. National programmes and individual scientists could do much of the identification and packaging of relevant information. The greatest challenge will be to obtain community co-operation in keeping the database up to date, and in respecting any management guidelines, zoning or reporting requirements that might be developed.

Community Participation

Working groups agreed that the research community would not voluntarily participate in any management program where a real need was not apparent. The path to building participation in management of research activities is thus one that focuses on current concerns and needs of vent scientists. Three approaches were discussed:

Exclusive use

The concept of ecological reserves for long-term observations has been discussed at previous InterRidge Meetings[1] and in articles that have appeared in the InterRidge News[2] and EOS[3]. Earlier discussions arose as a result of requests from investigators conducting time-series studies of vent communities at 13°N and 9°50'N on the East Pacific Rise. These studies focused on the relationship of community dynamics to the post-eruptive and longer-term evolution of hydrothermal systems, and, as such, were particularly sensitive to disturbances resulting from sampling and other interventions. No formal procedure for proposing or recognising exclusive reserves has been established although, in the two cited cases, an acceptable status quo is generally being respected. In part, this is a result of the relatively small size of the research community working in these areas, which eases informal communication and encourages co-operation.

As InterRidge and several national programs consider establishment of a global network of sites for integrated studies and long-term observations, adoption of more formal mechanisms for protecting time-series, observational studies may become necessary. One scenario discussed both prior to and during the workshop, would require investigators to make a formal proposal or request to the international community, through the InterRidge Steering Committee, for temporary exclusive use of a site for time-series observations. The research community would then be invited to comment on the proposal, following which the InterRidge Steering Committee could consider formal recognition. This type of open, democratic and peer-reviewed approval or recognition process was seen as essential to community acceptance of exclusive use zones.

Pilot Management/Zonation Projects

Workshop participants discussed a second means of responding to current research needs and developing community participation in the management of vent sites. This would involve establishing pilot management plans for 1 or 2 heavy use areas, such as Lucky Strike or 9°N EPR. Key elements of these management plans would be zonation of different research activities and a means of improving communication among researchers and groups. Dedicated, site-specific workshops were proposed as the most effective means of developing management plans that took into account the requirements of all concerned researchers.

Sample Redistribution

An important outcome of the 1995 InterRidge biology workshop at Rutgers University was the recognition of the need for a means of sharing sample material collected from vent sites worldwide[2]. The high cost of obtaining samples and potential impact of frequent sampling on vent communities justified development of an international sample-sharing program. Despite considerable effort, various proposals for voluntary reporting of sample collections and laboratory inventories did not succeed. While most participants at the Victoria workshop agreed with the merits of sample sharing, it was clear that another approach was necessary. A new suggestion was brought forward whereby the initiative would come not from the individual collecting the samples but rather from investigators requiring material for their research. Scientists or organisations would be invited to publish 'wish lists' on the InterRidge web site, so that investigators heading into the field would be able to make greater use of collected material. This mechanism could lead to new collaborations and would be particularly beneficial to scientists unable to participate in oceanographic expeditions.

References

[1] Sloan, H., Williams, R (eds.) (1996). *Workshop Report: Biological Studies at the Mid-Ocean Ridge Crest,* InterRidge, Durham 22pp.

[2] Mullineaux, L. *et al*., Deep-sea Sanctuaries at Hydrothermal Vents: A Position Paper, *InterRidge News*, Apr. 1998, 15-16.

[3] Mullineaux, L., Juniper, S. K., Desbruyeres, D, Cannat, M. (1998). Steps proposed to resolve potential research conflicts at deep-sea hydrothermal vents. *Eos, Trans. Amer. Geophys. Union*, 79: 533, 538.

Recommendations for Conservation and Sustainable Use of Hydrothermal Vent Sites

Recommendations for management

- The forthcoming International Seabed Authority's polymetallic sulphide deposits mining code should include strong environmental impact assessment (EIA) procedures.

- For the management of scientific research at hydrothermal vents, an EIA would provide an objective and recognized basis for deciding on the need for management or restricted access and in developing a management plan for heavy use or highly sensitive sites.

- The establishment of a central clearinghouse for information about research plans was identified as an important early priority for management and conservation. It might be possible for the InterRidge Office to fulfil such a role. Effective voluntary management requires that agencies and individual scientists communicate regularly with the designated clearing house to update the central database and to inform themselves prior to considering or initiating new research activities.

- Site-specific workshops might be organized to develop pilot management plans for one or two heavy use areas. These management plans would be designed to zone different research activities and to improve communication among researchers.

- Zoning a hydrothermal vent system according to the UNESCO Biosphere Reserve approach could be envisioned. Zoning objectives might include: (1) a core area devoted to strict protection and available only for non-invasive observational research; (2) a buffer zone where research and other activities compatible with specified objectives could take place; and (3) a transition zone where more invasive activities such as seabed mining could take place.

- Scientists requiring material for their research should be invited to publish "wish lists" for material located at hydrothermal vent sites (on the InterRidge web site). Field investigators could then make more efficient use of material collected at a site, thereby reducing sampling.

- Virtual tourism, "teacher at sea" programs, and the Russian example of mixing tourism with science should be encouraged. Such activities greatly increase public awareness of vent ecosystems and have minimal environmental impact.

Code of Conduct

A professional code of conduct for users of hydrothermal vent sites was suggested as a useful means to minimize conflicts and environmental impacts. Incentives may be needed to encourage marine scientists to comply with a professional code of conduct. National funding institutions could agree to demonstrated compliance with the code of conduct as a pre-requisite for further funding. Peer pressure also may play a role. The code might be adopted by the Intergovernmental Oceanographic Commission to emphasise its international significance. The following recommendations are made for incorporation into a Code of Conduct for users of hydrothermal sites.

Prior to initiating new research activities:
1) Investigate on-going research at the site by consulting appropriate sources such as:
- The InterRidge web pages or the NOAA web pages for the NE Pacific sites.
- Consult national programmes, *e.g.* RIDGE
- Consult site specific management plans where appropriate, *e.g*. The Endeavour Hot Vents Marine Protected Area

2) Notify InterRidge and national agencies, as appropriate, of intended cruise dates, sites of activity and types of activities.

When planning or conducting field work:
3) Contact other users (gather information, discuss compatible uses).
4) Avoid or minimise activities that:
- Cause long-term decline of the resource for future users
- Will decrease biodiversity at the site (ecosystem, species and genetic)
- Interfere with other on-going investigations, *e.g*. long-term observatories and other time-series studies
- Subsequently compromise the safety of underwater vehicles

5. Maximise efficiency in sampling (*i.e*. minimise waste, develop micro-analytical techniques and alternatives to physical sampling; make productive use of any excess material (co-ordinate use with other researchers).

Conservation Research

The final original goal of the workshop was to consider recommendations for conservation related research at marine hydrothermal vents. Time constraints prevented full development of this topic. Several areas where research was required to support future management and conservation efforts were identified during discussions. These include:

- Managing the impacts of all activities at hydrothermal vents requires an understanding of the ecological relationships between species and their responses to natural disturbances.

- At sites subject to heavy scientific use, knowledge of population sizes, dynamics, and genetic structures is needed in order to estimate an acceptable harvesting rate of organisms for laboratory studies.

- Experiments on the effects on hydrothermal vent species of sulphide particle discharges from mining operations are needed in order to estimate the real extent of environmental damage likely to be caused by mineral exploitation.

- A global data base on the distribution of hydrothermal vent sites and species would permit identification of species with restricted distributions and subsequently allow classification of vent sites according to their importance to species survival. This would be an ambitious undertaking that would require continual updating as new sites and species are discovered.

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