UNEP

CBD

CONVENTION ON BIOLOGICAL DIVERSITY

Distr.
GENERAL

UNEP/CBD/COP/5/INF/7
20 April 2000

ENGLISH ONLY

CONFERENCE OF THE PARTIES TO THE CONVENTION ON BIOLOGICAL DIVERSITY
Fifth meeting
Nairobi, 15-26 May 2000
Item 16.1 of the provisional agenda*

PROGRESS REPORT ON THE IMPLEMENTATION OF THE PROGRAMMES OF WORK ON THE BIOLOGICAL DIVERSITY OF INLAND WATER ECOSYSTEMS, MARINE AND COASTAL BIOLOGICAL DIVERSITY, AND FOREST BIOLOGICAL DIVERSITY (DECISIONS IV/4, IV/5, IV/7)

Information on marine and coastal genetic resources, including bioprospecting

Note by the Executive Secretary

I. INTRODUCTION

1. The present note has been prepared by the Executive Secretary to make available to the Parties information on marine and coastal genetic resources, including bioprospecting, in the context of the programme of work on marine and coastal biological diversity (decision IV/5, annex, operational objective 2.2) as part of the activity "to explore ways to expand the knowledge base on which to make informed and appropriate decisions about how the marine and coastal genetic resources might be managed in accordance with the objectives of the Convention". The note is based on available scientific literature, both formally published and from the Internet, and national reports, with inputs from experts drawn from the roster of experts hosted in the clearing-house mechanism of the Convention on Biological Diversity.

2. The note is intended to complement the study on the relationship between the 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 sea bed, being prepared by the Executive Secretary in consultation with the United Nations Division for Ocean Affairs and the Law of the Sea (UNDOALOS), in line with paragraph 12 of decision II/10 of the Conference of the Parties.

* UNEP/CBD/COP/5/1.

/...

3. Section II of the note presents the results of a survey of marine and coastal genetic resources and their use. After a brief description of the scope of marine and coastal biological diversity, a general account of its genetic-resource components is provided, as well as a description of their possible uses. Section III of the note provides examples of ongoing activities and instruments of various organizations related to marine and coastal genetic resources. Section IV draws some conclusions on the concept of marine and coastal genetic resources.

II. A SURVEY OF MARINE AND COASTAL GENETIC RESOURCES AND THEIR USE, INCLUDING BIOPROSPECTING

A. Marine and coastal biological resources

4. In the context of the Convention on Biological Diversity, "biological diversity" means "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part". "Genetic resources" means "genetic material of actual or potential value", while "genetic material" means "any material of plant, animal, microbial or other origin containing functional units of heredity".

5. Thus, marine and coastal genetic resources can be considered as marine plants, animals and micro-organisms, and parts thereof containing functional units of heredity that are of actual or potential value.

6. "Biodiversity prospecting" or "bioprospecting," is the exploration of biodiversity for commercially valuable genetic and biochemical resources. It can be defined as the process of gathering information from the biosphere on the molecular composition of genetic resources for the development of new commercial products.

7. Genetic resources can yield either small organic molecules called secondary metabolites, gene-encoding proteins such as enzymes, or metabolic pathways linking enzymatic reactions e.g. in a process known as microbial fermentation. Although there is still debate as to why organisms produce secondary metabolites, it is well known that these chemicals can have useful properties. These properties have been exploited by humans for millenia as medicines, pesticides, cosmetics, and more.

8. A survey of national reports and other sources shows that in their regulatory instruments, some Parties have introduced provisions that cover derivatives of genetic resources, synthetic versions of original material, biochemicals, "intangible components", associated knowledge. For example, the Andean Pact Common Regime on Access to Genetic Resources, established by the Andean Pact Decision 391 1/ defines access to include access to "derived products" from genetic resources (article 1). Derived products include molecules, combinations or mixtures or natural molecules including raw extracts of living or dead organisms (article 1). The Philippines legislation defines "by-product" as any part taken from biological or genetic resources including compounds indirectly produced in a biochemical process or cycle (Appendix A, Executive Order; section 2 (j), Implementation Regulations). "Derivatives" include extracts from biological or genetic resources such as blood, oils, resins, genes, spores and pollen taken from or modified from a

1/ The Andean Pact is a regional economic and political integration organization formed in 1969 by a treaty between Bolivia, Colombia, Ecuador, Peru, and Venezuela.

source product (section 2 (m), Implementation Regulations). Since much bioprospecting is directed towards the collection of such chemicals, they are considered in this document as derivatives of genetic resources. Derivatives may refer also to chemical compounds modified, created or synthesized from material originally obtained from organisms.

B. Marine and coastal biodiversity as a source of genetic resources

9. The oceans cover more than 70 per cent of the Earth's surface and extend to depths of more than 10,000 metres, but more species are known on land than in the sea (Gray, 1997). Although scientists do not agree whether the number of species in oceans is more or less than the number of terrestrial species.

10. Marine biological diversity is also well known for its extraordinary richness at the phylum level. Of the 33 known phyla, 32 are found in the sea - 15 exclusively so, while another 5 contain species of which more than 95% are marine. Representatives of most phyla occur in the benthos (Gray, 1997). or are associated with the bottom rather than planktonic (Angel, 1993).

11. Genetic diversity has two components: 1) among-species/population diversity and 2) within-species diversity. Within-species genetic diversity is higher on average in marine species than in freshwater species (because of larger population sizes), but among-species genetic diversity is greater in freshwater species (because of physical restrictions on gene flow) (Gray, 1997). Grassle (1991) argues that a considerable portion of the genetic diversity of the planet may be found among deep-sea organisms and recommends genetic studies of hydrothermal vent fauna which are naturally tolerant of high concentrations of toxic elements produced by the vents. High genetic diversity is found in species of marine algae (Wood 1989, in Gray 1997). Evidence is growing for high diversity of biochemical compounds in the sea as well.

12. Examples of coastal ecosystems include coral reefs, seagrass beds, oyster reefs, mangroves, salt marshes, and the continental shelf. However, with the exception of a few groups such as fishes and corals, most species in these systems are poorly studied (Bohlke and Chaplin, 1968; Springer, 1982; Achituv and Dubinsky, 1990; National Research Council, 1995, all in Heywood and Watson, 1995). Even coral reefs, with their highly diverse associated flora and fauna, are still relatively poorly described and their functioning is not well understood (Gray, 1997).

13. Higher marine species diversity is found among species of plankton and nekton in coastal ecosystems 2/ as compared to pelagic oceanic ecosystems. Some studies show that the greatest species diversity is in the tropics, particularly in South-East Asia and the South Pacific, the Indian Ocean, and the Caribbean Sea, making the waters surrounding developing countries in the tropics the richest marine source in the world for molecular genetic diversity (Norse 1993). A different pattern has been observed among organisms in soft sediments, with diversity increasing from shallow areas to the deep sea (Sanders, 1968 in Gray, 1997; Grassle and Maciolek 1993).

2/ The coastal oceans are considered in general terms to include the land margin affected by salt water (salt marshes, lagoons, mangroves, estuaries to the limits of tidal influence and penetration of salt wedges, coastal strips affected by sea-level rise, storms salt spray etc.), the continental shelves and the continental slope. They lie largely within the Exclusive Economic Zones of maritime nations. Several distinct hydrographic boundaries are usually observed within the costal oceans, which mark transitions between different types of benthic and pelagic communities and act as barriers to lateral exchanges of energy and nutrients between the terrestrial and ocean environments. (Global Change Report No 14).

14. The diversity of open-ocean 3/ taxa is poorly known for both higher and lower taxonomic levels (Grassle and Maciolek, 1992).

15. The most conservative estimate for the total number of species in the open ocean – half a million – is still at least twice the number of species described so far (May, 1992, in Gray 1997), and estimates range up to 10 million species (Grassle and Macioleck 1992 and May, 1992; Briggs, 1994, in Gray, 1997). In particular the significance of diversity within the microbial groups at the fundamental biochemical genetic level must be emphasized. Recent discoveries have brought to light unique and fundamentally different forms of life (Fuhrman et al. 1992; Fuhrman and Davis, 1994, in Heywood and Watson, 1995). Yet research in this area, especially on organisms inhabiting sediments, is just in its infancy.

16. Diversity among open ocean species has three peaks, depending on habitat: photic zone, benthic environments at depths of 2,000-3,000 metres (mostly on the continental slope), and abyssal plains (Vinogradova 1979; Grassle, 1991; Alongi 1992; Grassle and Maciolek, 1992; Angel, 1993; Poore and Wilson, 1993; Bray et al. 1994, in Heywood and Watson, 1995). The deep benthos harbours a much higher level of species diversity (Grassle and Maciolek 1992) and a higher proportion of local or regional endemic species.

17. Some studies support the view that these environments exhibit a latitude-driven (pole-to-tropic) gradient in the species diversity (Kendall and Aschan, 1993). On the other hand, it has been demonstrated that seaweed (macroalgal) diversity is higher in temperate latitudes than in the tropics, and lowest at high latitudes (Silva, 1992, in Gray 1997). In addition, the pole-to-tropic gradient in the southern hemisphere is far less pronounced since the waters around the Antarctic have high diversities for many taxa (Clarke, 1992, in Gray 1997). It seems probable that a cline of increasing diversity exists from the Arctic to the tropics, but the cline from the Antarctic to the tropics is far less well established, if it occurs at all (Gray, 1997).

18. Examples of open-ocean benthic ecosystems are hydrothermal vent communities and cold seeps communities. These communities support bacterial "mats" engaged in autotrophic primary production, as well as a limited number of heterotrophic species including zooplankton such as crustaceans and s iphonophores, grazers such as shrimps, and filter feeders such as mussels and tube worms (Jannasch et al., 1995).

19. For a long time the bottom of the deep ocean, which is aphotic and hence devoid of photosynthetic activity, has been likened to a desert in terms of species diversity. With no source of energy and carbon other than detritus from above, the ocean floor as an ecosystem produces no primary production from photosynthesis (Norse 1993). However, chemiosynthesis is common. Hydrothermal vents are mineral-rich regions in the ocean floor defined by the borders between tectonic plates. These vents are present at depths of 1800 to 3700 meters and are characterized by the ejection of superheated water that is saturated with minerals from underlying magma. These minerals include hydrogen sulfide, an energy source. An unusual hydrothermal vent community has evolved to exploit this energy source, and depends upon specialized chemolithotrophic

3/ Open ocean systems include all environments on Earth minus the landmasses and the continental shelf benthos. Biomes within the open oceans are defined by the intersection of four factors: energy source for primary productivity, physical structure, depth/light attenuation and latitude (UNEP, 1995).

bacteria and bacteria-like organisms of the kingdom Archaea for primary production. Archaea represent an extremely old kingdom of life, probably descending form the original cells to evolve on Earth (Woese et al. 1990). Woese and colleagues adopt a three-part taxonomy, consisting of Archaea, Eubacteria (bacteria), and Eukarya. Others suggest that this classification is unacceptable being primarily based on a very detailed gene sequence analysis, while organisms should be classified on the basis of their entire biology (Margulis, 1998). According to this view, Archaea and bacteria should be considered to belong to the same kingdom.

20. The only other known exception to the rarefaction of benthic biodiversity is the as yet poorly characterized communities existing in deep-ocean sediments associated with petroleum seeps (Rueter et al. 1994). Research expeditions drilling to 5,000 metres have discovered the presence of chemolithotrophic micro-organisms, apparently living off the carbon and energy sources provided by the petroleum. These microbes living within deep-ocean sediments may prove to be cosmopolitan, though further research is needed. Other organisms are found in these areas, such as tube worms, mussels, snails, eels, crabs, and fish.

21. To conclude, although a considerable part of biological and genetic diversity is found in marine and coastal areas, our knowledge in this field is still relatively poor, compared to the knowledge of terrestrial biological and genetic diversity. What is clear is that marine and coastal biological and genetic diversity represent valuable sources of genetic resources. The value of marine and coastal genetic resources is both environmental, since high genetic diversity is the key to adaptation to environmental change, and commercial, since these resources can be and already are the subject of bioprospecting and of biotechnological applications.

C. Actual and potential value of biodiversity in the marine and coastal environment

22. No comprehensive evaluation of marine genetic resources has been made to date. Fish stocks exploited by commercial and subsistence fisheries and unharvested populations of their relatives can all be considered as fish genetic resources, as long as they have some value. The many diverse aquatic organisms that comprise aquatic food-webs and that contribute to maintaining the structure of the ecosystem to which they belong can also be considered as genetic resources.

23. Much work has been done on the genetics of species used in aquaculture including: clams; Manila clam; oysters; peneid shrimps; salmonids (Lundin, and Zilinskas, 1995); and the orange roughy. Still, much of the world's aquatic fauna has yet to be evaluated for aquaculture potential, and most farmed fish have not yet been domesticated and are genetically close to wild types. Hence a wide diversity of farmed-developed (domesticated) fish breeds and broodstocks, as exists for crops and livestocks, has yet to be developed for aquatic species.

24. Genetic aspects of aquaculture have been reviewed, and it was concluded that current practices lead to reductions in genetic diversity, and maintenance of many breeds and meta-populations of marine species is needed (Gray, 1997). Yet the dependence of aquaculture on wild populations for broodstock or seed, and therefore its dependence on natural aquatic genetic resources, underlines the need for active participation of aquaculturists in

the development and evaluation of policies for the use and conservation of aquatic genetic resources (Wang, 1999). Genetic manipulation in aquaculture is also expanding rapidly and adequate safeguards against undesired or unanticipated effects on natural populations need to be developed.

25. Fisheries and aquaculture can have adverse effects upon fish genetic resources. Fisheries usually overexploit stocks, and some damage habitats through destructive fishing methods. Aquaculture can have large impacts on adjacent habitats, as it often requires large amounts of water, produces potentially undesirable effluents, spreads diseases, and leads to the destruction or fragmentation of habitats (e.g. mangroves). The release of hatchery stocks may have ecological and genetic implications for wild genetic resources. The genetic impacts of large-scale releases are likely to be negative when there are genetic differences between the hatchery stock and the wild population. The major potential genetic problems with enhancement programmes are the reductions of within and between stock genetic diversity and the displacement or replacement of wild stocks by released fish. In addition to the purposeful releases of fish to enhance fisheries (stock enhancement), farmed fish often escape from aquaculture facilities. Possible environmental consequences are the depletion or loss of wild fish stocks (e.g. by depredation, competition for food or territory or diseases), changes in natural aquatic habitats, and genetic change by interbreeding.

26. Other coastal marine organisms used for genetic resources research and development 4/ are sessile and/or soft-bodied invertebrates such as coelenterates (corals), tunicates, soft-bodied molluscs such as sea hares and nudibranchs, bryozoans, sponges, and echinoderms (sea urchins, sea cucumbers and starfish). These organisms often employ chemical defenses and other survival strategies due to the highly selective pressure of predation in coastal ecosystems, the highly dynamic physical features of these environments, and other factors. Genes found in marine organisms may be transferred to non-marine organisms to produce enhanced food; some marine substances may have important uses for the treatment of human diseases, as in the case of the compound monoalide, from a Pacific sponge, which has been tested as anti-inflammatory. Although known for their prominence in open ocean benthic areas, hydrothermal vent communities have been discovered also in cold water at shallow depths of 100 to 500 metres (DeLong 1992). The micro-organisms associated with these communities also yield interesting new chemicals that might be used in biotechnological applications, as techniques are developed for culturing them (see below).

27. In open-ocean systems, the deep sea and sea bed host a variety of organisms of actual or potential value as genetic resources, especially in light of the extreme environments in which they live. Commercial fisheries increasingly exploit deep sea fish and crustaceans, although little is known about these creatures and the impacts of human activities on their genetic legacies (Broad, 1997). Numerous creatures that inhabit the deep sea, such as fish and squids, as well as many of the shallow water taxa common in rocky shores and coral reefs, such as sponges, sea anemones, sea fans, lobsters, sea spiders and more, are all represented in the deep-sea environment.

4/ Scientific research often constitutes the first step in the process that leads to the discovery of organisms that eventually prove to have commercial applications and therefore become the object of bioprospecting. New technologies both to utilize and to document genetic resources have developed quickly over the last ten years. Genetic resources can now be described by a variety of extremely sensitive methods including nuclear and mitochondrial DNA analysis through sequencing, mini- and microsatellites, DNA fingerprinting, and restriction fragment length polymorphisms, and isozymes analysis which is comparatively easy and inexpensive and has a wealth of comparable data for many aquatic species.

28. Micro- and macro-organisms associated with hydrothermal vent communities constitute the focus of marine research and bioprospecting. These communities consist of giant tube worms, pencil-size Jericho worms with accordion-like tubes; orange worms covered with tiny bristles; small benthic worms that wriggle through the mud; and finger-length, dark red palm worms that stand upright, topped with wig-like fronds. A special class of small worms (alvinellids) lives on the walls of mineral deposits that form around vents. Mussels, shrimp, clams, and crabs are abundant at many vents, but these do not belong to the same species as those found in coastal systems (Stover, http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/ps_vents.html).

29. The source of energy for these deep-sea communities is terrestrial rather than solar (Jannash, 1988). It consists of the inorganic materials contained in the vent fluids and gases. In particular, hydrogen sulphide, a chemical that is toxic to most forms of life, is converted into organic matter that the animals can consume with the help of sulphide-oxidizing bacteria that live either in symbiosis with the vent animals or in the environment surrounding them. The discovery of this bacterial community has opened opportunities for basic research on these chemosynthetic organisms, characterized by a molecular structure allowing them to live in water exceeding 100°C and at extremely high pressure (hyperthermophilic bacteria).

30. Marine invertebrates, usually sessile and/or soft-bodied, have intrigued marine natural product chemists for decades, and have been screened by scientists according to a so-called "bio-rational" approach. The argument is that, due to their vulnerable body plans or the extreme environmental conditions in which they often live, these invertebrates must have evolved effective chemical defences as a survival strategy (Scheuer, 1990). In fact, some products deriving from marine and coastal organisms, such as toxins and enzymes, are noteworthy for exhibiting highly complex chemical structures and for showing peculiar properties that can have applications in various areas.

31. While the potential molecular diversity among marine macro-organisms is high, the potential molecular diversity among micro-organisms, both terrestrial and marine, is probably higher still, perhaps by orders of magnitude (Paleroni ,1994). Many micro-organisms, including dinoflagellates, can be cultured directly from the water column. Recent work on culturing micro-organisms isolated from the water column, marine sediments including oil seeps, such as those observed in the deep ocean, or from marine animal hosts, has yielded a promising array of new chemicals (Fenical, 1993).

32. As the technology for culturing marine micro-organisms develops, it is likely that interesting organisms will be discovered in a wide range of marine hosts. Thus, conventional predictions about which marine species will yield economically valuable chemicals may be invalid. If it is true that most if not all marine species provide critical microhabitats for micro-organisms producing potentially valuable compounds, this would imply a high biodiversity value for all marine organisms, compounding the value of highly diverse ecosystems such as coral reefs. It is estimated that less than 1 per cent of potentially useful chemical-producing organisms have been screened to date.

D. Specific examples of the value of marine and coastal biological diversity

33. The areas of application of marine genetic resources can be several and varied and often coincide with the main areas of application of marine

biotechnology, such as seafood-supply enhancement; commercial and industrial applications of marine substances and processes (including pharmaceuticals and biomedical applications) and environmental monitoring and control and bioremediation.

34. Efforts have been made to exploit the tremendous phyletic diversity of marine biodiversity in order to identify useful compounds for commercial exploitation. Recently major pharmaceutical and agrochemical companies, that traditionally have exploited the more defined terrestrial systems, have turned their attention towards the need to study the tremendous potential provided by the less defined marine environment. They have been brought to the realization of the importance of these resources as the result of novel discoveries that have major economic potential. As a result, several new joint industry-university cooperative ventures are being initiated.

35. In the next decade several products from marine organisms now in pre-clinical development will be marketed and a host of new bioactive compounds will enter preclinical phases. Several anti-tumour compounds promise to be powerful agents for future cancer therapy. In addition, anti-inflammatory products from sponges and other marine organisms may well be routinely used to fight arthritis, asthma, and other inflammatory diseases. Antibiotics isolated from sponges, sea whips and other marine organisms may well be marketed for the treatment of infections in man and farm animals within a few years.

36. Furthermore, within the next several years, genetically engineered micro- and macro-algae will be developed that can be used either for the production of specialty chemicals such as vitamins, aminoacids, agar, or for the production of methane, alcohol, oil and other high-energy products. Readers will find a more detailed treatment of the subject in Lundin, C.G. and Zilinskas, R.A. 1995.

37. Specific examples of the application of marine and coastal genetic resources and their derivatives, including bioprospecting, are provided in the following paragraphs:

(a) Antineoplastic agents

38. A class of molecules, isolated from a Caribbean tunicate, *Trididemnum solidum*, shows a variety of antiviral and antineoplastic properties, depending upon the type of side chain. It should be noted that one of these compounds has entered clinical trials and has showed a number of side-effects (Rinehart *et al.*, 1981).

39. Bryostatins are a class of macrolides from the Pacific bryozan *Brugula nertina*, that appears to be very promising anti-tumour agents (Lundin and Zilinskas, 1995). Other types of bryostatins have been isolated from the marine ascidian, *Aplidium californicum* (Lundin and Zilinskas, 1995). None have become commercialized yet.

(b) Antibiotics

40. Marine micro-organisms and a wide variety of other marine organisms are rich sources of compounds with anti-microbial activity (Lundin, C.G. and Zilinskas, R.A. 1995). It is believed that the chemical defense mechanisms (which include the production of organic antibiotic compounds) of sea whips

(stationary organisms that proliferate in an environment dominated by a number of potential predators) help to some degree protect them. One species, Pterogorgia guadalupensis, has a compound that has proven very effective against both Staphylococcus and Mycobacterium strains. Sponges have antibiotics that inhibit the growth of a variety of microbes. For example, Ircina variabilis produces and antibiotic referred to as varibilin, which is very active against species of Staphylococcus (Lundin and Zilinskas, 1995). The sponge Acanthella, produces a variety of antibiotics collectively referred to as kalihinols (Lundin and Zilinskas, 1995).

41. Many organisms that produce anti-microbial compounds also produce cyclic compounds with potential anti-inflammatory activity. In fact several compounds isolated from sponges have both anti-microbial and anti-inflammatory activities. For example, the Pacific sponge, Luffariella variabilis, produces an antibiotic called manoalide that is active against both Streptomyces and Staphylococcus.

(c) Specialty chemicals

42. In addition to unique compounds that are useful for biomedical purposes, marine organisms harbor numerous other compounds useful for a variety of other commercial applications, such as: aminoacids, lipids, vitamins, fats, waxes, sugars, polysaccharides, pigments, and other compounds. An example of economically important compounds is provided by chitin. This is one of the most abundant polymers in the world constituting the shells of crabs, lobsters, shrimps, krills, and other marine organisms that are routinely harvested in large quantities. It is used for a large variety of industrial applications including for example adhesives, chelating agents, paper and textile additives, structural matrices, etc. (Lundin and Zilinskas, 1995). The use of chitin in promoting wound-healing and for other biomedical uses are potentially even more impressive. In addition Hardiger and his colleagues (1984) (Lundin and Zilinskas, 1995) have shown that chitosan can protect crops against some pathogenic fungi.

(d) Marine polysaccharides

43. There are three important commercially significant algal polysaccharides that are useful specialty chemicals (Lundin and Zilinskas, 1995). These are agar, carrageenan and alginate. The first two are produced from red algae while the last is generated from brown seaweeds. These three polymers have a combined annual market value that ranges well in the hundreds of millions of United States dollars. The highest-quality agar comes from Gelidium species found along the coasts of mainly Spain, Portugal, Mexico and Japan. As a result of harvesting pressure and its slow growth rate, this important agar-producing species is in danger of being depleted. Cheney and his colleagues are using somatic cell hybridization to produce new, culturable strains of high-quality agar-producing seaweeds. They are hybridizing species of a fast growing algae, like Gracilaria, with high-quality agar-producing species of Gelidium to produce a fast growing seaweed that can be cultured and will produce high-quality agar.

(d) Vitamins and carotenoids

44. Several commonly cultured marine algae are excellent sources of vitamins, especially vitamins B12, B1, C, biotin, riboflavin, nicotinic acid, and pathothenate. However, of the 22,000 to 26,000 known algal species, only

about 60 have been surveyed for vitamin content or any other potentially useful specialty chemicals or bioactive metabolites. This is a significant untapped resource of biological diversity that merits extensive research.

(e) Marine adhesives

45. Many marine mussels and other invertebrates secrete a type of glue that allows them to adhere to rocks and other materials in the presence of water. Waite and his collaborators at the University of Delaware, in the United States of America have isolated one of these glues and determined its structure. The type of product that may result from these studies could be used for, inter alia, underwater cement materials, marine plywoods, marine paints, dental cements, surgical applications, repair of broken bones. Polysaccharide marine glues have also been identified in a variety of marine bacteria.

(f) Marine micro-organisms and enzymes

46. Hyperthermophilic bacteria are being studied in order to understand their characteristics and in terms of the possibility to manipulating them for commercial purposes and isolating commercially important heat-resistant enzymes. Their ability to withstand very high temperatures would greatly enhance chemical reaction rates and, at the same time, reduce contamination by more temperature sensitive organisms. Research in this field is just at the beginning, but the preliminary results are very promising. For example, the ability of one of the major microbial species to use carbon dioxide (CO_2) and hydrogen sulfide (H_2S) as energy sources for chemosynthesis means that it may be useful for converting harmful industrial H_2S into less volatile sulfates. Other bacteria produce H_2S and therefore represent potentially useful organisms for desulfurization of coals. Other hyperthermophiles are methanogens that may more efficiently facilitate biomass conversion into methane than other low-temperature bacteria.

47. To conclude, bioprospecting offers an opportunity to derive income from the process of natural products research and development, creating economic incentives for biodiversity conservation. This process involves extracting economically valuable information (in the form of chemical structures, gene sequences, information on biological activity such as catalytic properties, or fermentation processes in the case of microbial isolates) from naturally occurring genetic resources. The use of naturally occurring genes by biotechnology industries has the potential to offer numerous benefits to all countries.

III. EXAMPLES OF ORGANIZATIONS AND INSTRUMENTS ADDRESSING MARINE AND COASTAL GENETIC RESOURCES

48. Genetic resources are vital to ensure the continued evolution of species in response to changing environments and to both human-derived and natural stresses. Their importance has generated significant responses through the establishment of conservation and use programmes, to ensure that they will be available in the years ahead. The centres of the Consultative Group on International Agricultural Research (CGIAR) have to a limited extent started assembling collections of a few species of fin-fish, crustaceans, mollusks and other invertebrates. They are also working with the Food and Agricultural Organization of the United Nations (FAO) on the conservation of cultured fish genetic resources.

49. The main work of the International Center for Living Aquatic Resources Management (ICLARM) on genetic resources in the marine environment is carried out at its Coastal Aquaculture Center (CAC) in the Solomon Islands. The organisms involved are giant clams, pearl oysters and sea cucumbers characteristic of the coral reefs flats, slopes and shelves and lagoons that comprise coral-reef resource systems. The principal objectives of the CAC are the development of sustainable, small-scale, farming systems and fisheries enhancement systems for coastal villagers living adjacent to coral reefs. The CAC does not currently undertake any ex situ genetic resources conservation work, although cryopreservation techniques for sperm and larvae are fairly well established for some bivalve molluscs and might be contemplated in the future in connection with specific medium-term projects. Live, wild caught broodstock of sea cucumbers are held in tanks on a transient basis, used for spawning and then replaced on the reefs. In the case of giant clams and pearl oysters, the CAC maintains in situ broodstock in fully controlled marine protected areas. The species involved are the giant clams Tridacna crocea, T. derasa, T. gigas, T. maxima, and T. squamosa and Hippopus hippopus; and the pearl oysters, Pynctada margaritifera and P. maxima. The larger species of the clams, T. derasa and T. gigas and H. hippopus are threatened species, having been extinguished in many parts of their ranges, whereas all of the other species have been seriously reduced in abundance by overexploitation in many areas of the tropical Indo-Pacific.

50. With regard to fishery genetic resources, the goals and activities of FAO concentrate on four main areas: (i) documentation and characterization of genetic diversity; (ii) identification of threats and opportunities; (iii) identification and evaluation of new technologies; and (iv) assessment of trends, e.g., in resource status, development, demography, etc. Documentation and characterization are the vital first steps in the conservation and sustainable use of genetic diversity. Knowledge of the genetic resources base available to fish farmers in the form of genetically diverse populations or genetically improved breeds will help to optimize production, to manage broodstock more effectively, and to evaluate selection programs. Fishery managers will need to know the genetic stock structure of wild populations to stock-specific harvest quotas in order to minimize risk of species transfers, choose appropriate stock for fisheries enhancement, and identify and manage species or "evolutionarily significant units" that may be at risk of extinction.

51. An International Conference on the theme "Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources" was organized by the ICLARM in association with the Inland Water Resources and Aquaculture Service and the Sustainable Development Department of FAO at the Bellagio Conference and Study Center of the Rockefeller Foundation, Italy, in 1998 (Pullin et al., 1999). The conference concentrated on the present status of and likely requirements for policies for the conservation and sustainable use of aquatic genetic resources. 5/

52. Another example of international workshop in the field is the international workshop on fish genetic conservation with the theme "Action Before Extinction", organized by the World Fisheries Trust in 1998. During

---

5/ A summary of the actions suggested by the Bellagio Conference to sharpen the focus of the Convention on Bioloigcal Diversity in this sector, alongside the identified areas of concern, where there is a need to clarify the conceptual, social, scientific and political bases for taking action and for new initiatives with respect to aquatic genetic resources can be found at http://www.fao.org/fi/newslet/fannews/news%5Fit.asp.

this workshop various papers were presented to give an overview of fish genetic conservation issues, as well as to describe genetic conservation programmes of greater or lesser magnitude in a number of countries (Harvey et al., Action Before Extinction, 1998, see http://www.worldfish.org/abe_viewproceedings.htm).

53. Marine and coastal genetic resources are mainly to be found in situ, as wild populations in seas, rivers, lakes, reservoirs and associated wetlands. Large ex situ gene banks, equivalent to crop seed banks are less feasible for fish because of the high costs of keeping live collections and because for most fish only spermatozoa (not eggs and embryos) are amenable to cryopreservation. However limited collections of fish germplasm are held in publicly funded institutions and by the private sector.

54. In some cases, gene-banking is a solution for maintaining genetic variability. Gene-banking can be considered as a tool for collecting and managing genetic material, not only for convenience but also because, in many cases, wild broodstock are becoming more difficult to find. Collections of fish genetic resources for breeding programmes are of increasing interest to private corporations. An example of a gene bank is the International Fisheries Gene Bank (IFGB), a programme of the Canadian non-governmental organization World Fisheries Trust, dedicated to the preservation of wild stocks. The IFGB provides training programmes in the theory and practice of genetic conservation, including cryopreservation techniques that are field-oriented, inexpensive and require little equipment, and assist governments and agencies to develop policies for the collection and exchange of fish genetic material. The IFGB was formed in 1992 and currently holds over 3,000 accessions of salmonid germplasm from six species and 29 stocks, representing both wild populations and privately held broodstocks.

55. A growing range of techniques is now also available for culturing symbiotic micro-organisms such as bacteria and cyanobacteria, and algae from the tissues of fish and other macro-organisms. Culture collections are vital for the maintenance of macro- and micro-organisms. A genetic resource collection is a repository of samples of living material of animals, plants fungi or micro-organisms, generally in a dormant or other phase in which they are not actively growing, which have been assembled for use in breeding or other purposes. Especially in the case of micro-organisms, because of the difficulties of making fresh isolations from nature, genetic resource collections are also the only effective way by which we can have access to micro-organisms or indeed determine their very existence.

56. Several institutions are currently carrying out projects aimed at collecting marine organisms, in order to gather further information on these organisms and to screen them for useful compounds that might be used for commercial applications. Some examples, intended to be purely illustrative of this kind of research and development in the field of marine genetic resource, are provided below.

57. The Australian Institute of Marine Science (AIMS) is involved with national and international partners to seek public benefit from Australia's marine biodiversity. Through a project on marine bioproducts, biota from a wide range of marine environments have been collected and screened for useful compounds, some of which have been advanced to the first stages of commercialization. During the first stages of the project, the existing database of 10,000 macro-organisms was expanded by isolation of 6,000 micro-

organisms creating a unique and very valuable inventory of biodiversity that will provide feedstock for many years of analysis. The search for novel biochemicals is complemented by research on organismal responses to environmental stress. Marine organisms produce chemical signals, venoms, anti-fouling agents, and biochemical means of protection from harmful environments. Understanding how these agents work has wide potential for commercial and biomedical applications (http://www.aims.gov.au/pages/research/trp/pages/trp2-48.html).

58. The Marine Science and Technology (MAST III) Programme of the European Commission also has turned its attention to the large variability of the marine environment as well as the enormous amount of micro-organisms per volume of seawater, as additional multiplicators of biological diversity. It is recognized that although the phylogenetic and metabolic diversity of marine micro-organisms is probably the greatest among all forms of life, due to methodological problems, bacterial diversity and the biotechnological exploitation of bacterial genes in the oceans remain largely unknown.

59. The overall objective of the research project is the development and application of a new molecular strategy to turn the hidden biodiversity of marine bacteria into novel biotechnological products. This strategy is based on an integrated molecular approach using gene cloning and expression of marine bacterial genes, estimation of the organismal structure of the gene carrying bacterial communities in situ, and molecular characterization of bacterial isolates. The final objectives, which will be achieved with the molecular analysis of marine genes and bacteria in combination with microbiological and biotechnological studies, include the production of strains for commercial products, such as a variety of novel psychrophilic and mesophilic enzymes; and the development of an intelligent strategy for the assessment of microbial diversity in any natural environment and its biotechnological potential, i.e. how and where to look, with what molecular approaches, for which products (http://www.gbf.de/margenes/Margenes.html).

60. Marine biotechnology research initiatives are also carried out within university research programmes. For example, the University of Delaware Sea Grant focuses on exploring, developing, and using the adaptational prowess of marine organisms. One of the Sea Grant projects is combining the exploration of the diversity, ecology, and evolutionary history of the micro-organisms that thrive at deep-sea hydrothermal vents. Molecular methods are being coupled with microelectrode technology to examine submillimetre-scale variation in concentrations of oxygen, manganese, iodine, iron, and hydrogen sulfide, all of which are thought to determine the distribution of microbes living in hydrothermal vent communities. These microbes are considered to be of great interest to industries that need enzymes able to withstand high temperatures and pressures. The aim of the project is to isolate the enzymes from selected samples and screen them for potential applications in biotechnology (http://www.ocean.udel.edu/seagrant/Research/marinebiotech.html).

61. Jamstec (Japan Marine Science and Technology Center) is currently performing observational research on deep-sea organisms. In 1997, it performed the following research on deep-sea organisms: structure and biota analysis of the communities and examination of the dispersal process of chemosynthetic communities; studies of the relationship between environmental factors and ecotypes; search for valuable resources (http://www.jamstec.go.jp).

62. In terms of instruments providing guidance on research, management and use of these resources, in the context of the above described activities, technical reports and studies have been produced. As far as international legal regimes governing the use of these resources, they seem to be subject to the provisions of the Convention on Biological Diversity and the United Nations Convention on the Law of the Sea, and customary international law. These aspects are, as stated above, being addressed in the context of the study on the relationship between the two conventions, which is called for in decision II/10.

IV. CONCLUSIONS

63. Although a considerable part of biological and genetic diversity is found in marine and coastal areas, our knowledge in this field is still relatively poor, especially if compared to the knowledge of terrestrial biological and genetic diversity. What is clear is that marine and coastal biological and genetic diversity represents a valuable source of genetic resources.

64. No comprehensive evaluation exists of marine genetic resources screened to date, but wild fish stocks as well as domesticated stocks used for the purpose of aquaculture are considered as genetic resources. Other organisms that constitute genetic resources include invertebrates, macro- and micro-organisms, especially in light of their chemical structures and peculiar properties, which can have applications in different areas. The fast pace of development of marine biotechnology is likely to facilitate the discovery of a wide range of new molecules and functions of marine and coastal biodiversity.

BIBLIOGRAPHY

Angel, M.V. (1993) Biodiversity of the pelagic ocean, Conserv. Biol. **7**, 760-72

Broad, W.J. (1997) The Universe Below, Simon & Schuster, New York

Burke (1994) State Practice, New Ocean Uses and Ocean Governance Under UNCLOS 13 – paper presented to the 28th meeting of the Law of the Sea Institute, Honolulu, Hawaii, 11-14 July 1994

DeLong, EF. (1992) Archaea in coastal marine environments, Proc. Natl. Acad. Sci. **89**, 5685-5689.

Fenical, W. 1993. Chemical studies of marine bacteria: developing a new resource, Chemical Reviews **93(5)**, 1673-1683.

Grassle, J.F. (1991) Deep-sea benthic biodiversity, Bioscience **41**, 464-9

Grassle, J.F. and Maciolek, N.J. (1992) Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. Am. Nat. **139**, 313-41

Gray, J.S. (1997) Marine biodiversity: patterns, threats and conservation needs, Biodiversity and Conservation **6**, 153-175 / Marine Biodiversity: patterns, threats and development of a strategy for conservation, Rep.Stud.GESAMP, (62)

Heywood, V.H. and R.T. Watson (eds) (1995). Global Biodiversity Assessment, University Press, Cambridge, for United Nations Environment Programme.

Jannasch, HW, CO Wirsen & T Hoaki. (1995) Isolation and cultivation of heterotrophic hyperthermophiles from deep-sea hydrothermal vents. In: Archaea: A Laboratory Manual. Themophiles, pp. 9-13, FT Robb, K Sowerd, AR Place, HJ Schreier, SD Sarma & E Fleischman, eds (Cold Spring Harbor Press, Cold Spring Harbor, New York, USA).

Kendall, M.A. and Aschan, M. (1993) Latitudinal gradients in the structure of macrobenthic communities: a comparison of Arctic, temperate and tropical sites, J. Exp. Mar. Biol. Ecol. **172**, 157-69

Lundin, C.G. and Zilinskas, R.A. (1995) Marine Biotechnology in the Asian Pacific region, Proceedings of the 16-20 November 1993 Conference, World Bank, Gotab, Stockholm

Margulis, L. (1998), Symbiotic Planet, Basic Books, New York

Norse, EA, ed. (1993) Global Marine Biological Diversity, A Strategy for Building Conservation into Decision Making (Island Press, Washington, DC, USA).

Paleroni, NJ. 1994. ASM News 60(10), 537-540.

Pullin, R.S.V., Bartley, D.M., and Kooiman, J. (1999), Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources, ICLARM-FAO.

Pullin, R.S.V. and Casal, C.M.V. (Eds.) Consultation on fish genetic resources, ICLARM Conf. Proc., 51 (1996)

Rueter, P, R Rabus, H Wilkes, F Aekersberg, F Rainey, HW Jannasch & F Widdel. 1994. Anaerobic oxidation of hydrocarbons from crude oil by new types of sulfate-reducing bacteria. Nature **372,** 455-458.

Scheuer, PJ. (1990) Some marine ecological phenomena: chemical basis and biomedical potential, Science **248**,173-7.

Wang, Yuan L., 1999, Utilization of Genetic resources in Aquaculture: A framer’s view for Sustainable Development).

Woese, CR, O Kandler & ML Wheelis. (1990) Towards a natural system of organisms: Proposal for the domains Archaea, Bacteria, and Eucarya. Proc. Nat. Acad. Sci. **87,** 4576-4579.
