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University
UNU/IAS
Institute of
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國際聯合大學高等研究所

Environmental aspects of marine genetic resources

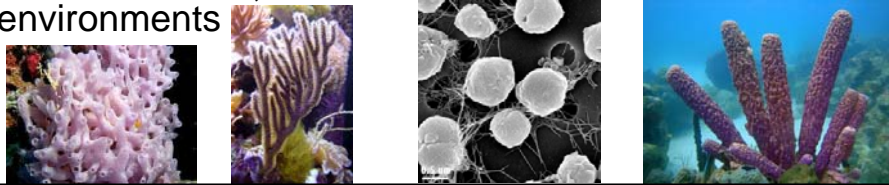
Marjo Vierros, UNU-IAS

Marine genetic resources

- Genetic resources in the world's oceans are of actual and potential interest for commercial uses
- The ratio of potentially useful natural compounds is higher in marine than terrestrial organisms
- There is a higher probability of commercial success with marine-sourced material
- There are numerous patents based on marine genetic resources and products on the market
- Only 1-2 percent of pre-clinical candidates become commercial products

Common marine organisms used for commercial purposes

- **Marine sponges** have shown promise for treatment of cancer, asthma, alzheimers, arthritis, inflammation, etc.
- **Corals** (particularly soft corals), **molluscs** (sea slugs, sea hares, cone snails), **tunicates**, **worms** (including hydrothermal vent tubeworms), **bryozoans**, **algae**, **vertebrates** (fish, sharks)
- Deep sea **micro-organisms**, including extremophiles from hydrothermal vents, and bacteria and archaea from sediments, the water column and other ocean environments



Finding geographic area of origin

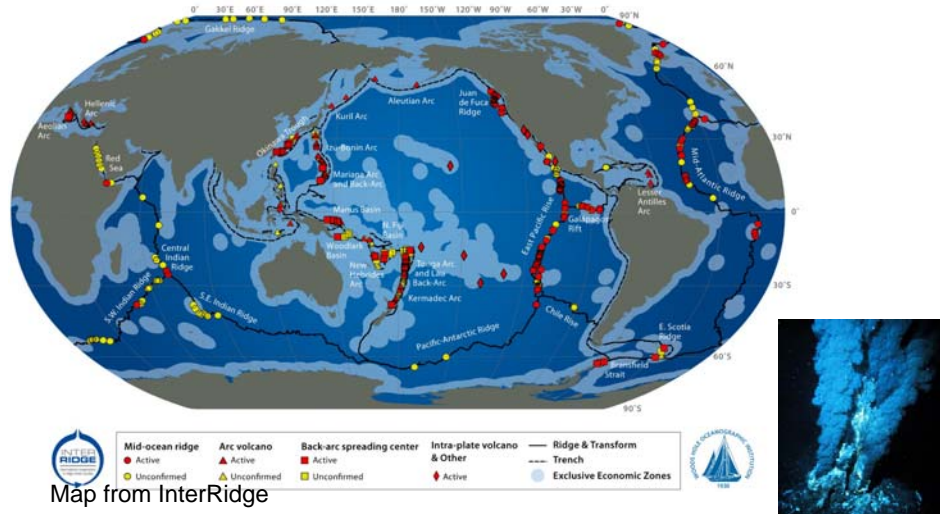
- Patenting can be used as a proxy of commercial interest
- Most patents and products based on organisms from coastal areas or EEZs
- In general, it is often difficult to tell the exact geographical location where a specimen was collected
- Very few patent documents contain exact coordinates, some have a more general description of collection location, such as “a deep sea hydrothermal vent”, “the Mid-Ocean Ridge” or the “East Pacific Rise”, which may or may not be beyond national jurisdiction
- Original scientific literature often contains coordinates – time consuming to trace
- **We looked in more detail at hydrothermal vents, deep water corals and sponges, and open ocean habitats.**

Patents associated with hydrothermal vent organisms

- Hydrothermal vents contain micro-organisms (archaea and bacteria) that have adapted to extreme environments, and thus have properties of interest to biotechnology.
- Looked at approximately 80 hydrothermal vent micro-organisms, and found patents and applications associated with approximately 50 of them
- Some organisms had several patents associated with them (ex. *Thermococcus litoralis* associated with 50 patents and a product – found in both shallow and deep vents)
- Many organisms can be found in both coastal and offshore vents, but some exclusive to a specific environment
- Majority of patents from vents within EEZs, although some come from beyond national jurisdiction.

Many patents related to hydrothermal vent micro-organisms

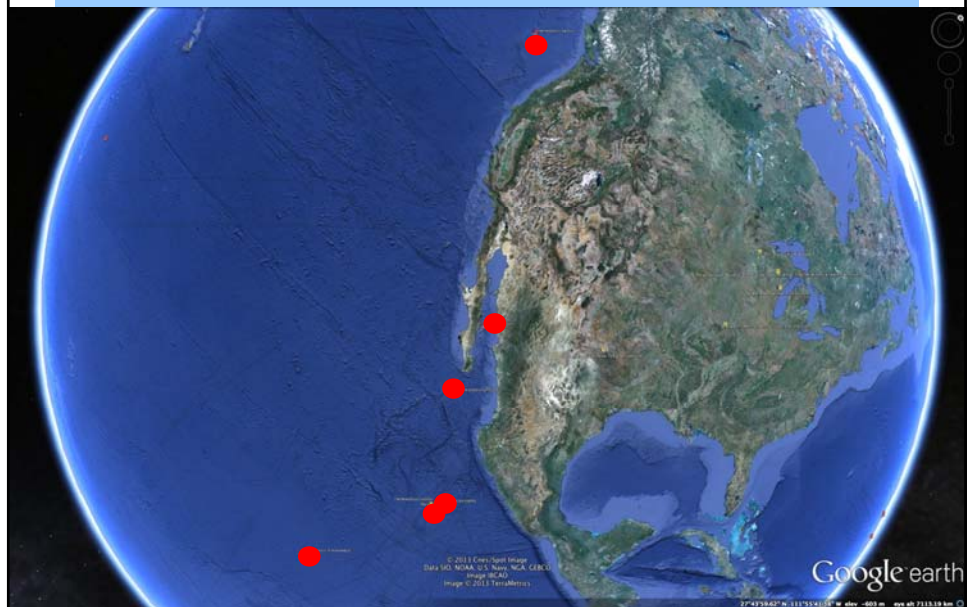
Global Distribution of Hydrothermal Vent Fields



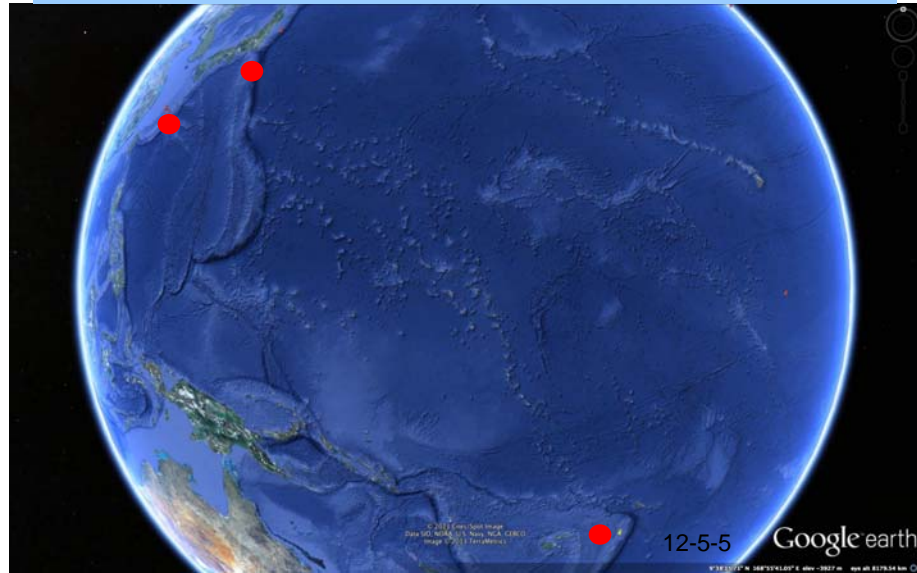
Mid-Atlantic Ridge patents



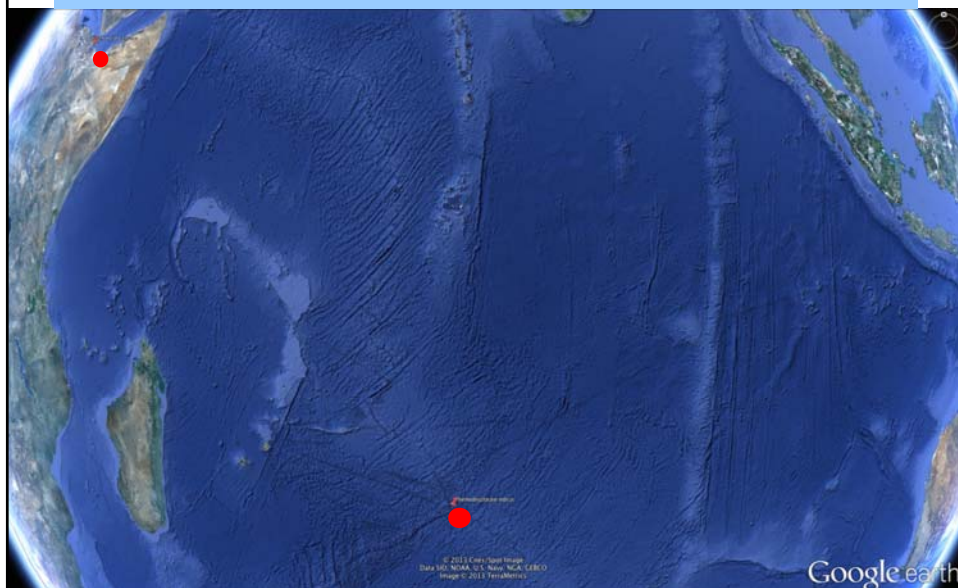
East Pacific



West Pacific



Indian Ocean



Examples of patents/applications likely from beyond national jurisdiction

- ***Pyrolobus fumaria*** - patent US 7781198 for **polymerase to be used in biotechnology**. Verenium Corporation (2010, 2012). Also US7056703 (2006), US7049101 (2000), WO2003023029, WO2002020735
- ***Pyrodictium abyssi*** –WO2005094543 for **proteins and nucleic acid encoding**. Verenium Corporation (Diversa). Also patent US 7459172 (2008)
- ***Thermococcus barophilus*** – contributor to US 20110045489 (New England Biolabs) and US 20100311142 (Korea Ocean Research and Development Institute) for **hydrogen production**
- ***Thermococcus marinus*** KR20100064731 for a **heat-resistant DNA polymerase**. Univ. Sungkyunkwan, Korea
- ***Vibrio diabolica*** – US 7,015,206 Polysaccharide for use in **bone repair and other medical purposes**. US patent, Institut Francais de le Recherche pour l'Exploitation de la Mer (2006)
- ***Alcanivorax dieselolei*** - CN 1904033 (2007) for **environmental remediation** – bacteria degrade alkanes (saturated hydrocarbons). No. 3 Institute of Oceanography, China
- ***Thermodesulfatator indicus*** –US 20110008848 amino acid sequence and potential uses in biotechnology by GeneSys Ltd, UK.

Some examples of commercial developments

- **Fuelzyme™ enzyme** was developed on the basis of samples collected from a deep-sea hydrothermal vent, likely from the Mid-Atlantic Ridge. This enzyme, which is currently marketed by Verenium (USA), is used in ethanol production from corn
- **Vent polymerase** is a thermostable enzyme sourced from a hydrothermal vent archaeobacteria in Italy. It is marketed by New England Biolabs (USA) for use in DNA cloning, sequencing and amplification.
- **Venuceane™**, an enzyme showing antioxidant properties, based on the bacteria *Thermus thermophilus* collected in the Guaymas Basin, Gulf of California at 2000m of depth. The enzyme is marketed by the French company Sederma for use in cosmetics.

Cold-water coral reefs



Map by Hugo Ahlenius, UNEP/GRID-Arendal



Cold-water coral reefs

- For decades, gorgonians (soft corals) have been source of compounds of interest for pharmaceuticals
- Pseudopterosins were originally isolated from the marine soft coral, *Pseudopterogorgia elisabethae*, and are now of significant commercial importance because of their anti-inflammatory and anti-proliferative properties.
- Deep water corals do not have symbiotic algae
- They have cold-adapted microbial communities that may help them survive and may contain novel compounds of interest
- Active area of scientific research
- **Quick search found 2 patents specifically related to cold water corals (both related to pharmaceuticals), one from within national jurisdiction, one of unknown origin**

Deep-water sponges



- Marine sponges are among the richest marine sources of pharmacologically-active chemicals
- Thousands of interesting compounds have been discovered from sponges and associated bacteria, and one of the very first drugs was discovered from a sponge
- An area of active research
- **A quick search found ~ 40 patents relating to deep sea sponges (within national jurisdiction)**
- **Compounds in clinical or pre-clinical trials (Discodermolide, Dictyostatin-1, Topsentins)**
- **Halaven (from a deep sea sponge from New Zealand) approved by USA FDA as a cancer drug**
- **Could eventually command a US\$1-billion/year market**

The open oceans

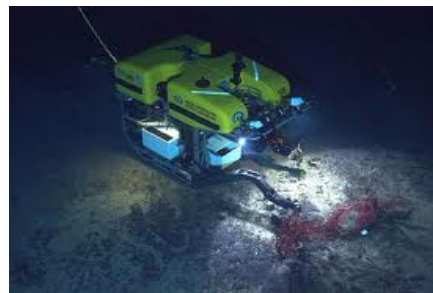


- Open ocean micro-organisms (bacteria and archaea) are largely unknown, but a source of active research and biotechnology interest
- Open ocean bacteria have yielded potential anti-cancer medicines (*Micromonospora marina*) and enzymes that are able to function at low temperatures (*Pseudoalteromonas haloplanktis*)
- 10 to 100 billion organisms per liter of sea water, **large potential for discovery**
- Craig Venter's Sargasso Sea expedition found 1800 species of microbes, including 150 new species of bacteria, and over 1.2 million new genes
- Results in public on-line database
- This has led to a number of new patent applications related to sequencing/classifying Sargasso Sea and other open ocean microbes and their uses (e.g. US 20070015237, US 7,638,073, 20100304462...)

Potential for environmental impact?

- At the early stages of collection, impacts minimal to non-existent
- Repeated collection of a promising species may cause impact (larger quantities likely needed)
- Producing synthetics may eliminate the need for harvesting
- If continuous harvesting is required, impact may be a concern
- Impact is a concern if the target organism is rare, has a restricted distribution, and/or the collection is focused on a particular population or may impact on a pristine or sensitive environment.
- Data on marine environments, species and populations is lacking, making risks difficult to assess
- Any pressures caused by collection may, in some cases, be cumulative with other environmental pressures

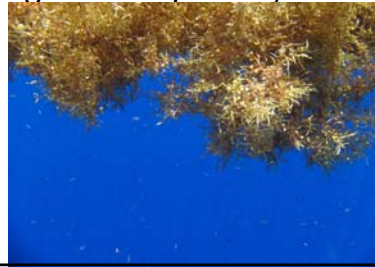
Common sampling methods



Potential environmental impact case study – Sargassum weed

- *Sargassum natans* mentioned in 75 patents ranging from biofuels to pharmaceuticals, including extraction of gold from water.
- **Patents for use of Sargassum weed in biofuel** production, including ocean fertilization to increase biomass - (US 7479167, 7985267 and US 20080124446)
- A search for “sargassum and biofuels” turns up 84 patents and applications (for a variety of Sargassum species)

– **Environmental impact concerns?**



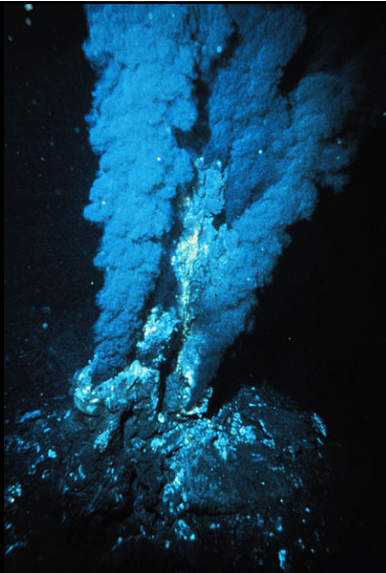
Potential environmental impact case study – Krill

- Krill are found in all of the world's oceans and are an important part of food webs
- Over 400 patents related to krill for uses ranging from krill oil, pharmaceuticals, aquaculture feed, cosmetics, food industry and many others
- Krill = “pink gold”
- Krill is also potentially impacted by climate change



EIA/SEA

- Environmental impact assessment (EIA) and strategic environmental assessment (SEA) are currently rarely undertaken (except Madrid Protocol)
- Current EIAs sector-based or region-specific, **making it difficult to look at cumulative impacts in the world ocean**
- Such assessments should address the large scale of ocean ecosystems, connectivity of localized and separated ecosystems, and the specific characteristics of deep seabed and pelagic open ocean species, their trophic structures, and their environments



Thank you!