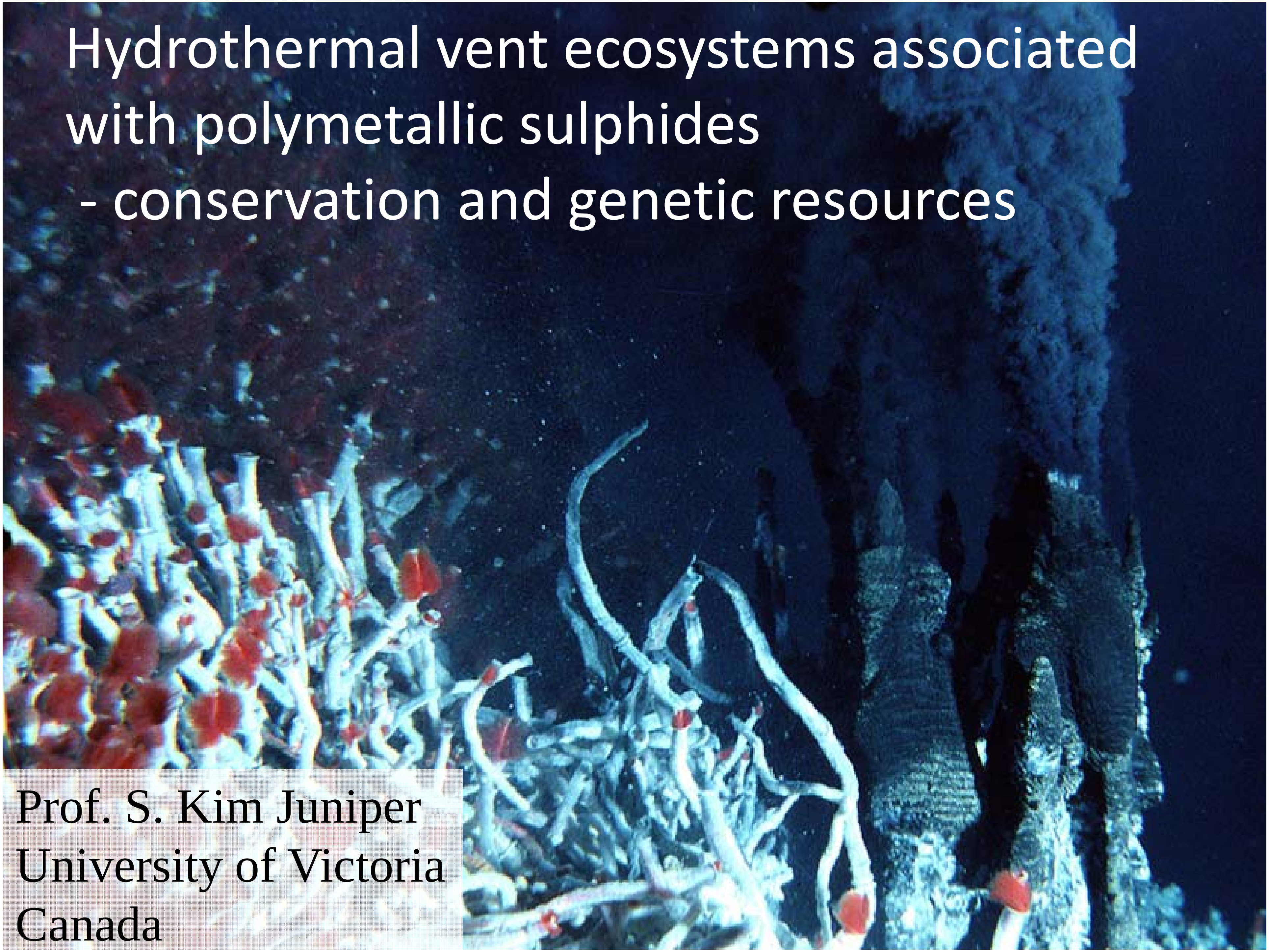


Hydrothermal vent ecosystems associated with polymetallic sulphides - conservation and genetic resources

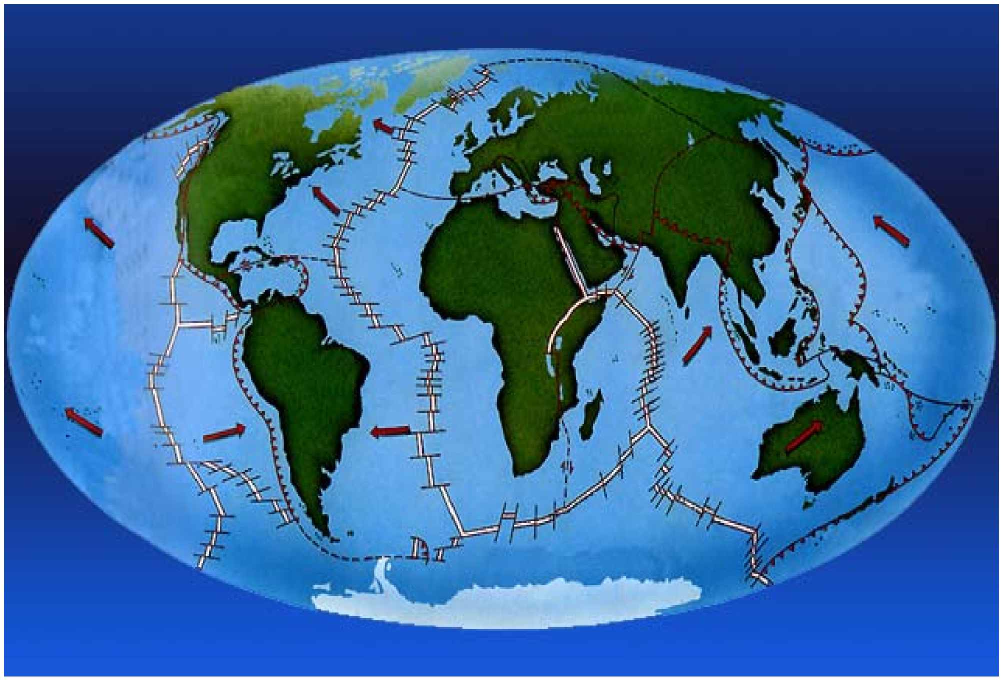
Prof. S. Kim Juniper
University of Victoria
Canada

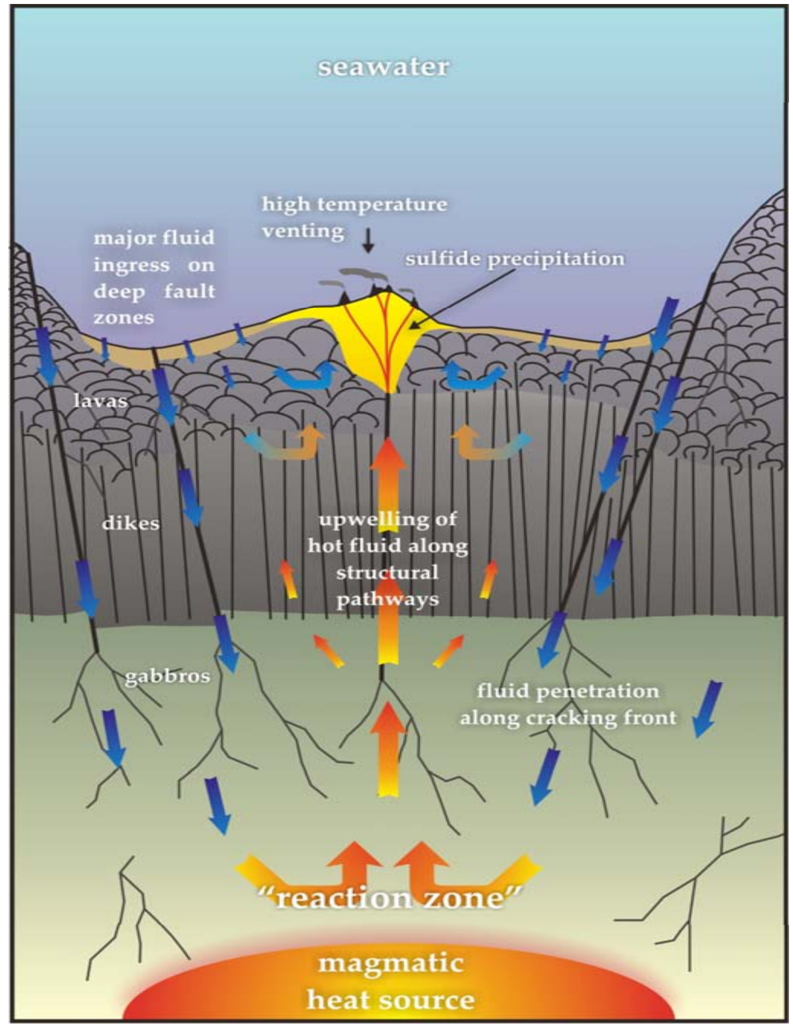

Dry land:
29%
Sea-
floor
under
less than
2 km
of water:
11%
Sea floor
under more than
2 km of water: 60%
Earth's Surface

The Deep Sea – an energy desert

- No light = no new food production from photosynthesis
- Animals feed on organic debris or fallen carcasses
- Low abundance, slow growth - but high biodiversity
- Poorly sampled – estimated 500 000 to 10 million species

Hydrothermal venting at tectonic plate boundaries



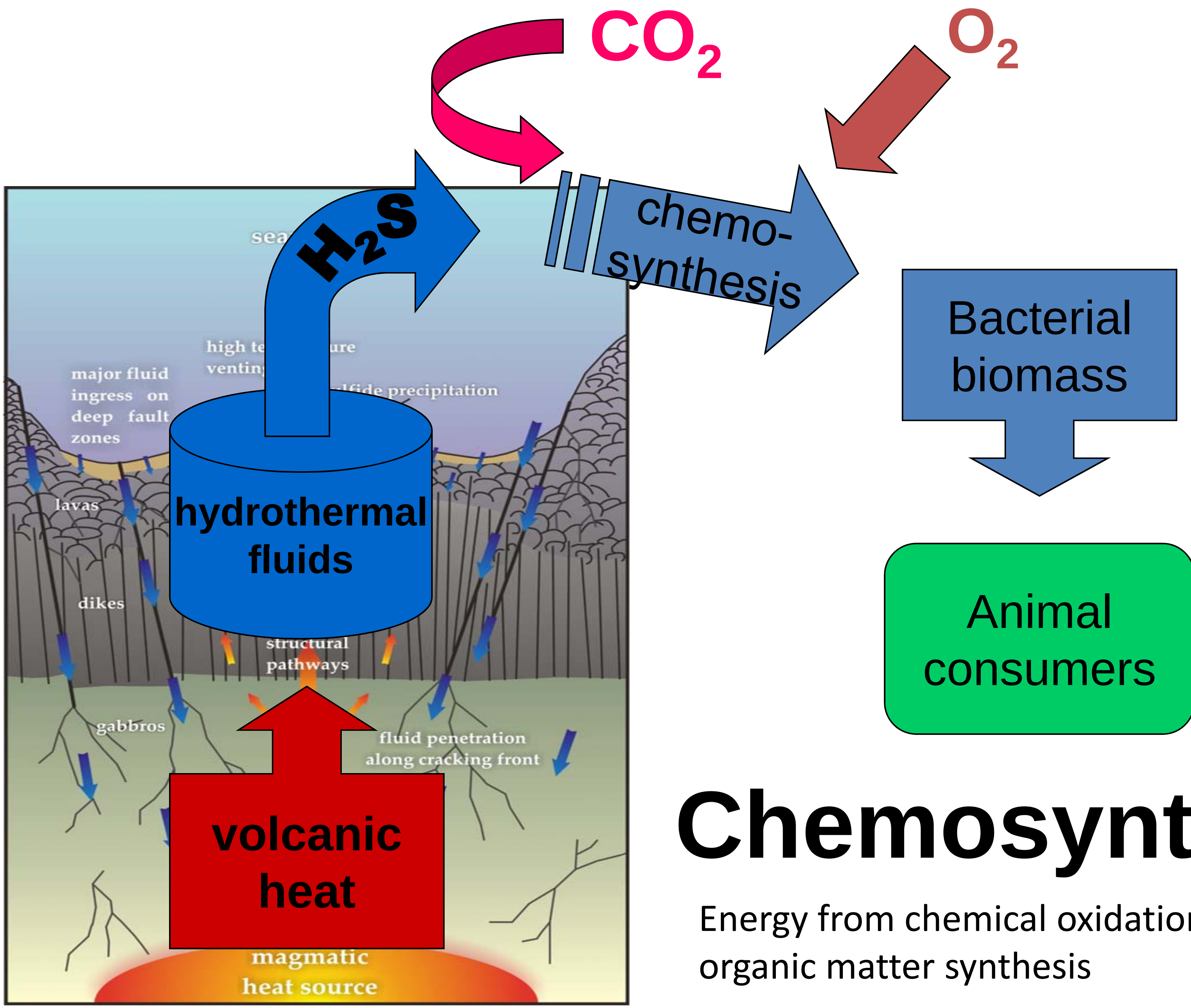


Hydrothermal vents - energy oases for specialized ecosystems

Specialised animals and microbes colonise seafloor vents

H_2S in hydrothermal fluids provides energy for *chemosynthesis* of new organic matter

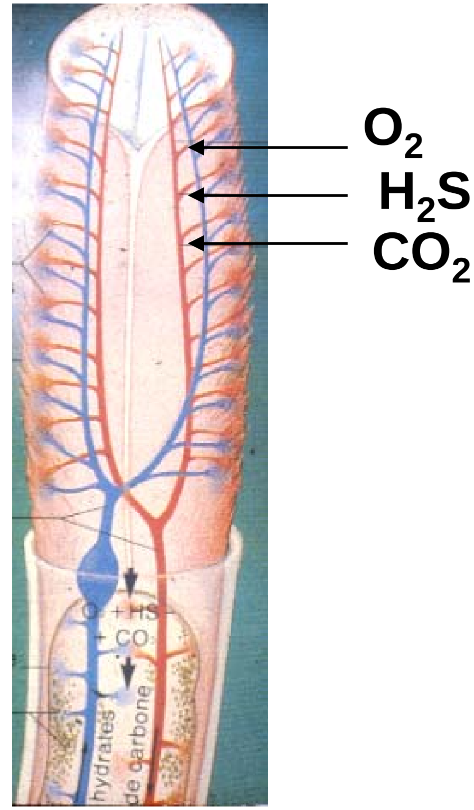
- High biomass
- Rapid growth
- <u>Low</u> animal diversity
- High microbial diversity



Chemosynthesis

Energy from chemical oxidations fuels organic matter synthesis

The tubeworm symbiosis



$HS^- + 2O_2 = SO_4^{-2}$

Energy

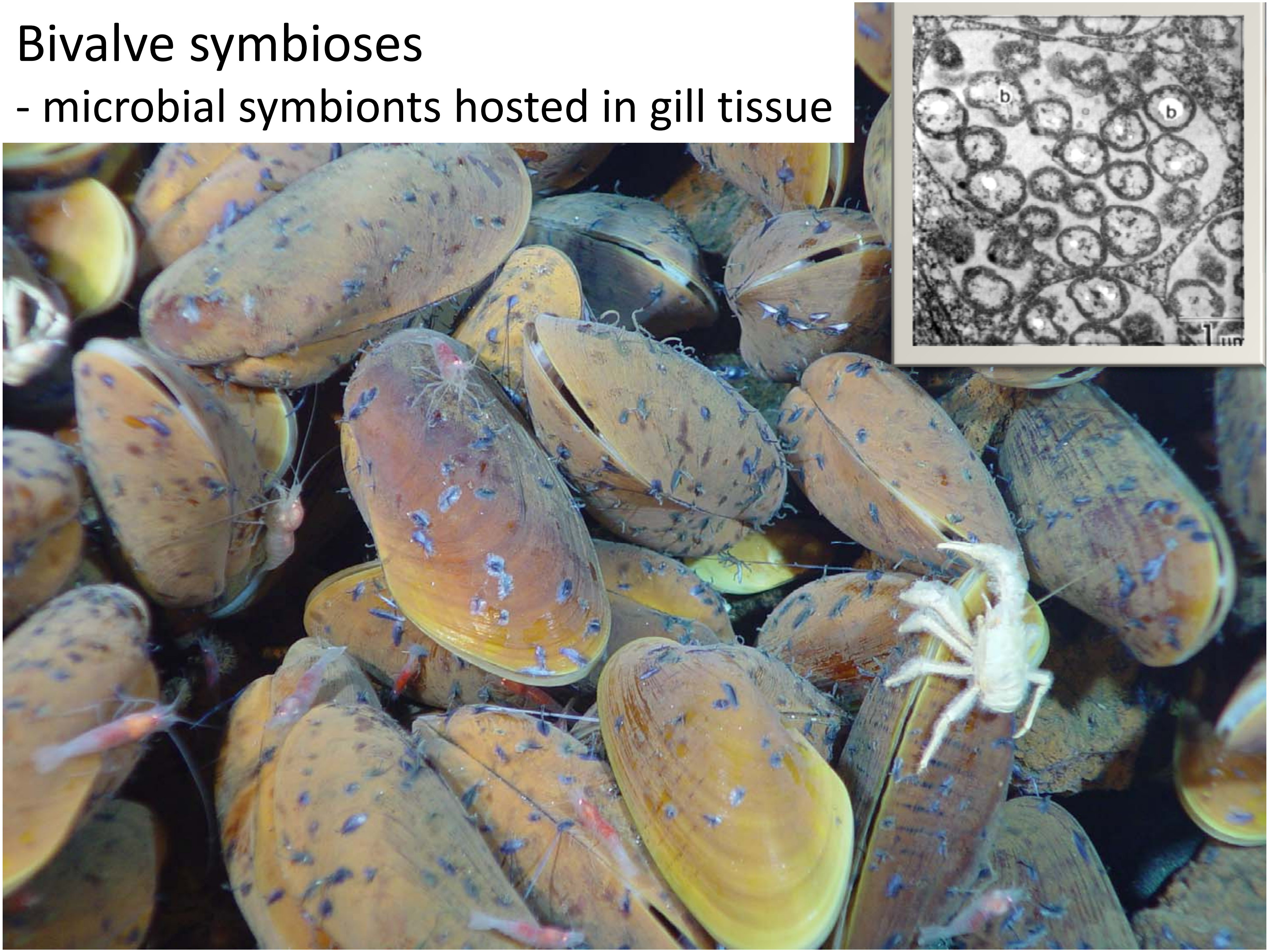
CO_2 + R = organic molecules

Giant tube worms have no mouth or digestive system

- entirely dependent on symbionts for food

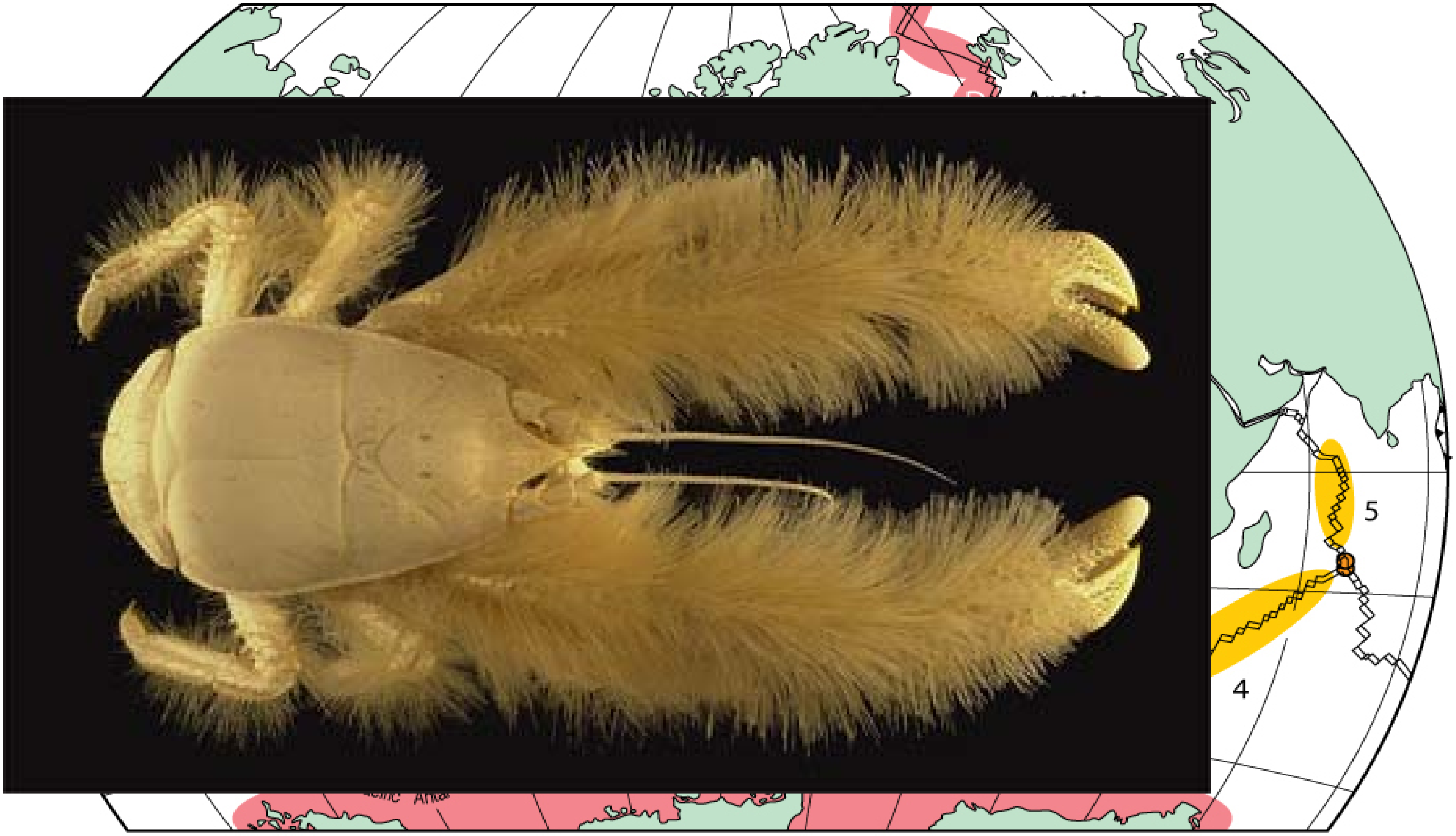
Bivalve symbioses

- microbial symbionts hosted in gill tissue

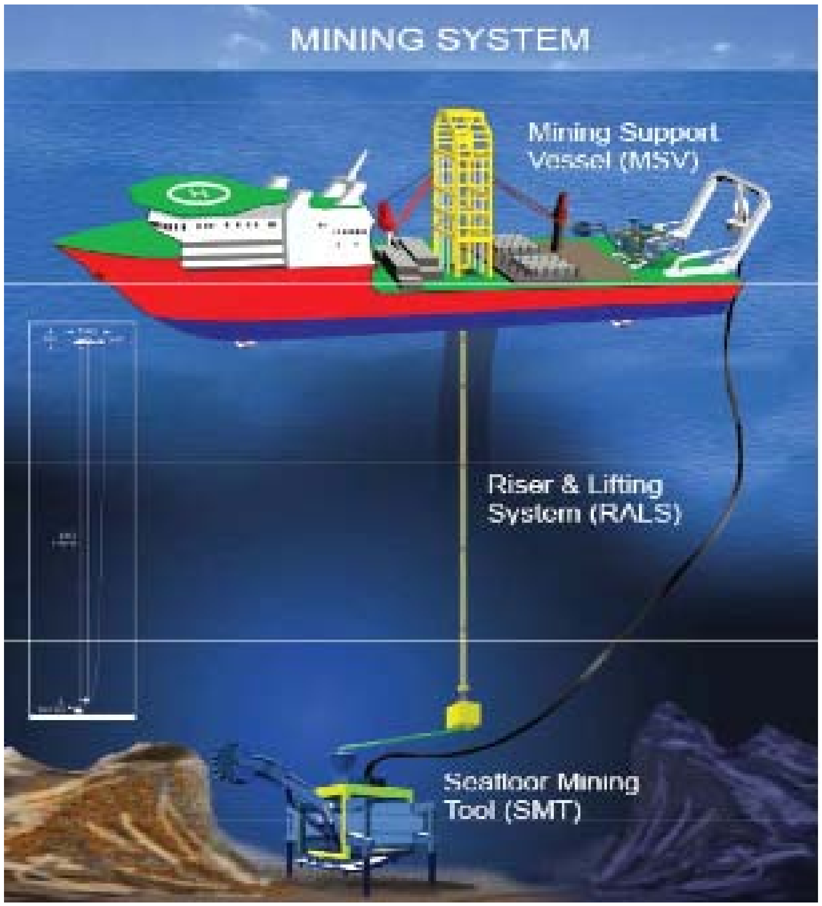


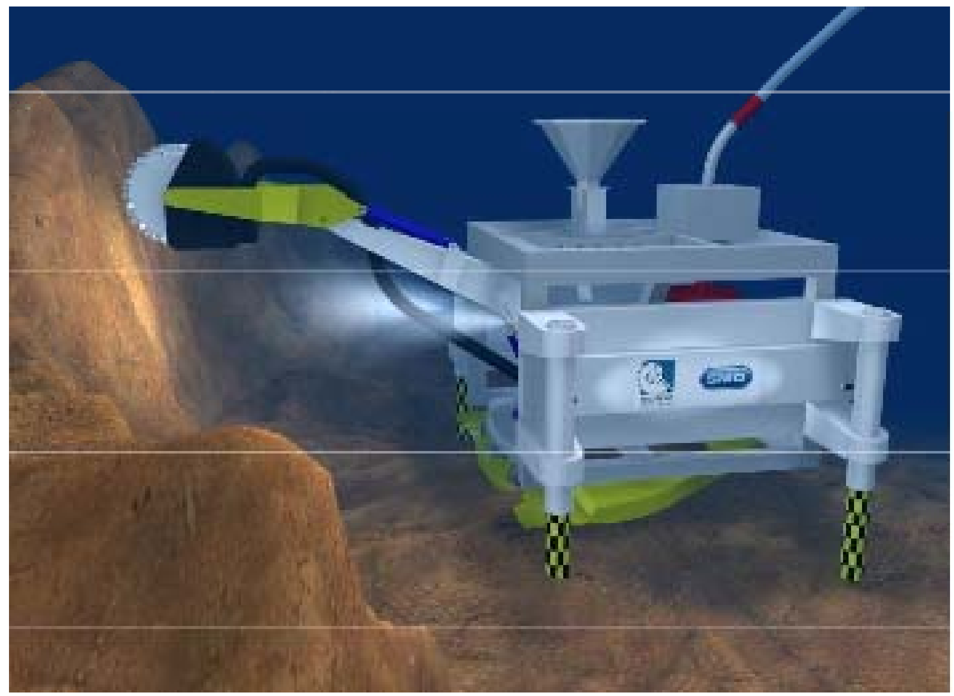
Free-living microbes (biofilms and microbial mats) feed other vent organisms

700+ known hydrothermal vent species



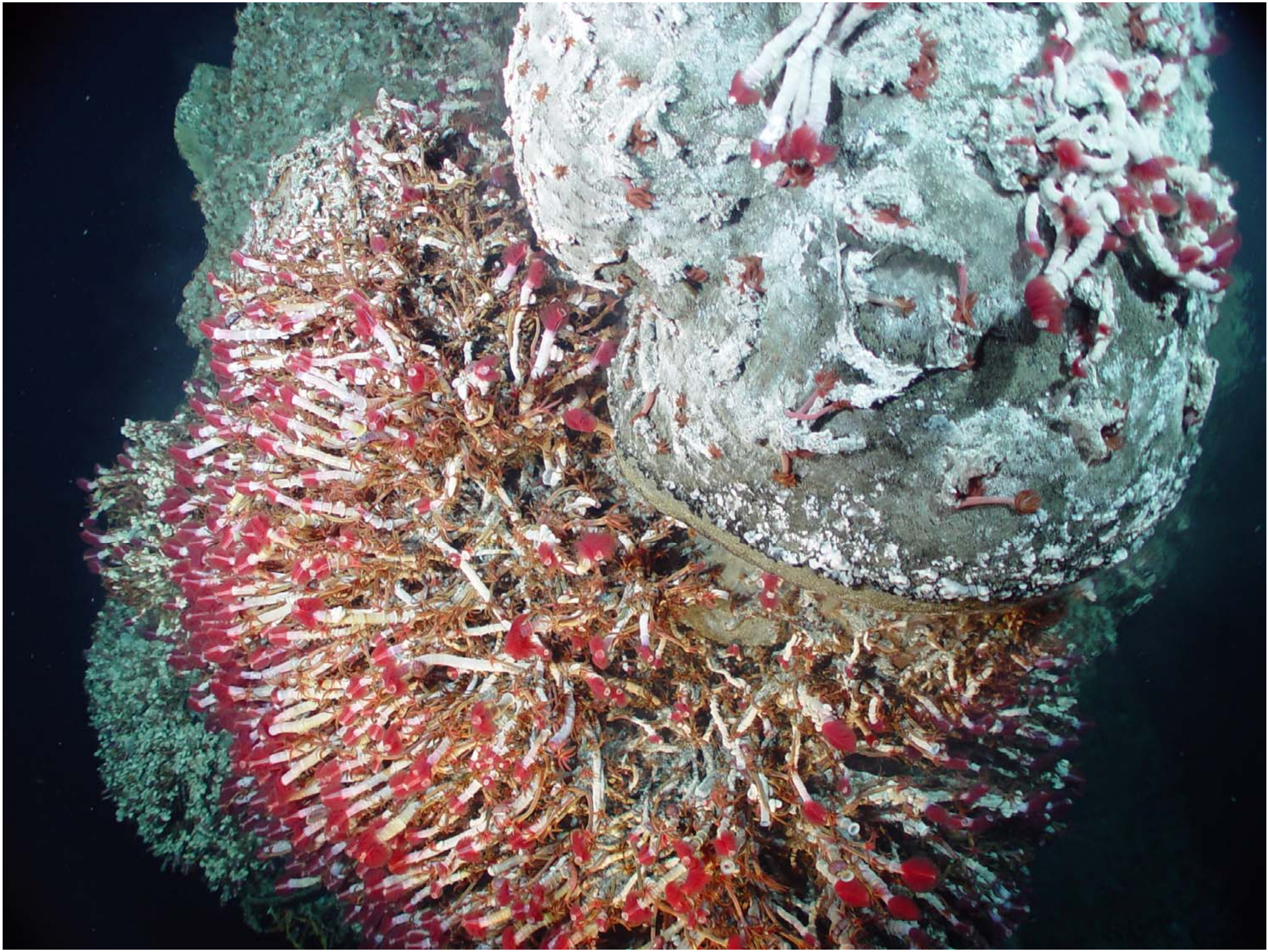
Impact of mining on hydrothermal vent ecosystems



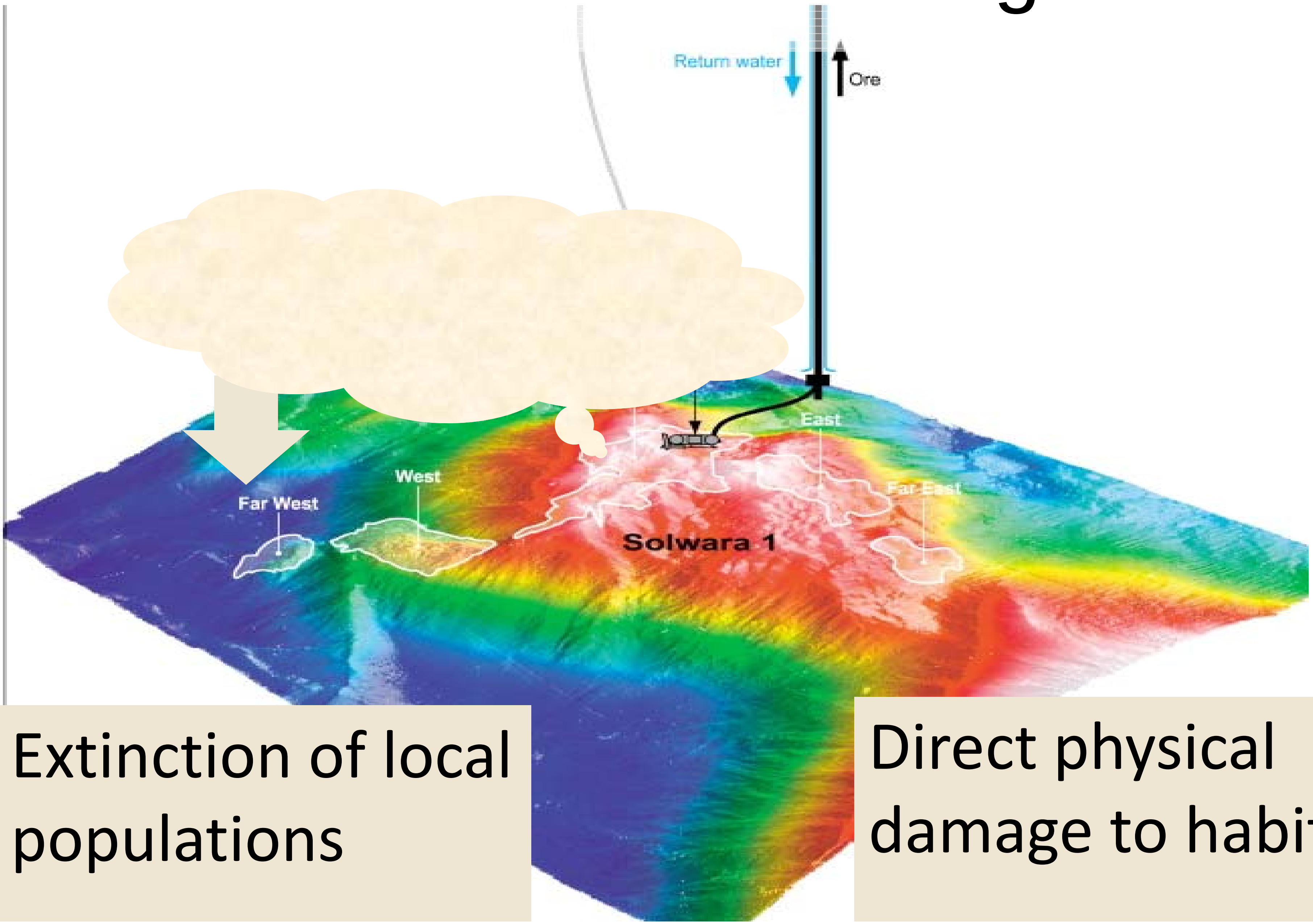


Images from Nautilus Minerals

Mineral deposits are habitats for vent organisms



Effects of mining



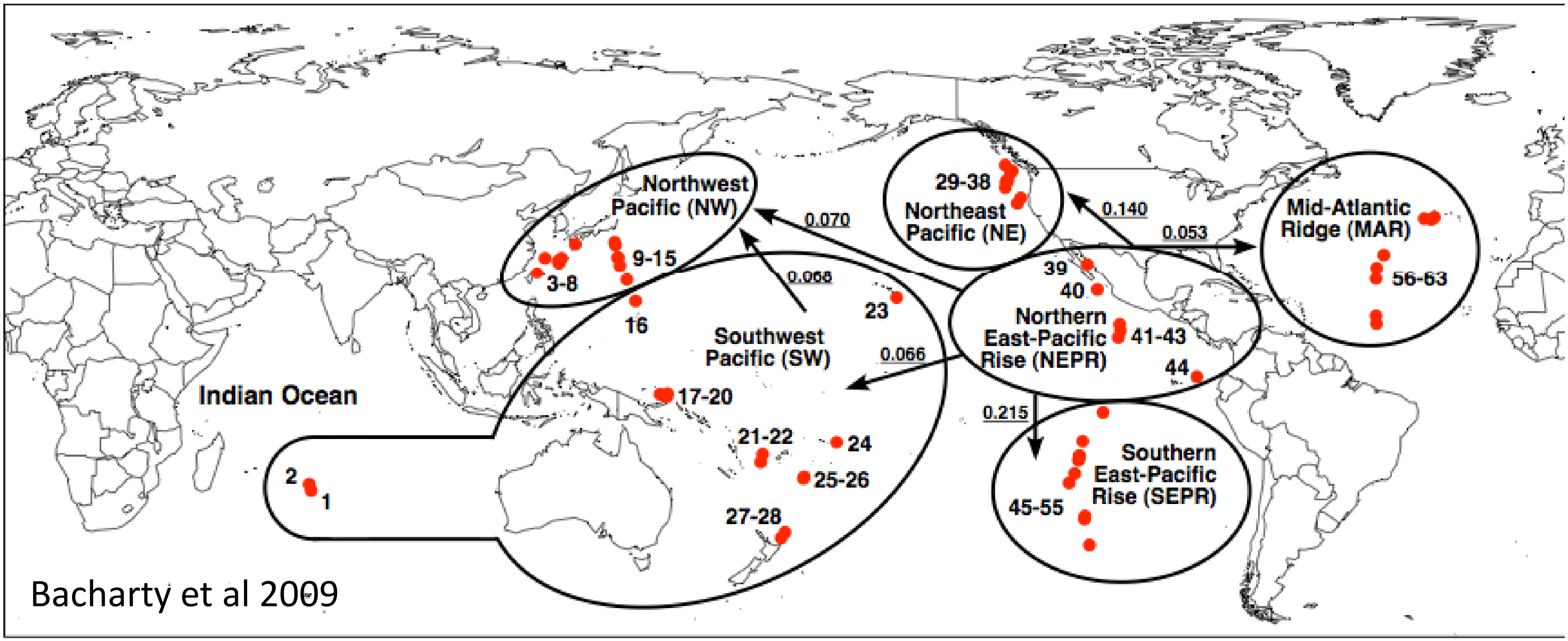
Extinction of local populations

Direct physical damage to habitat

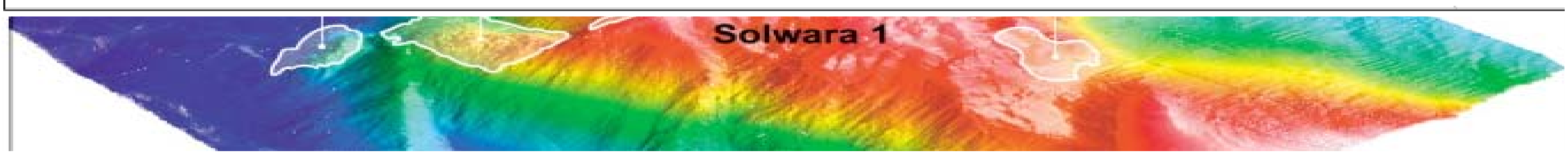
Effects of mining – also depend on

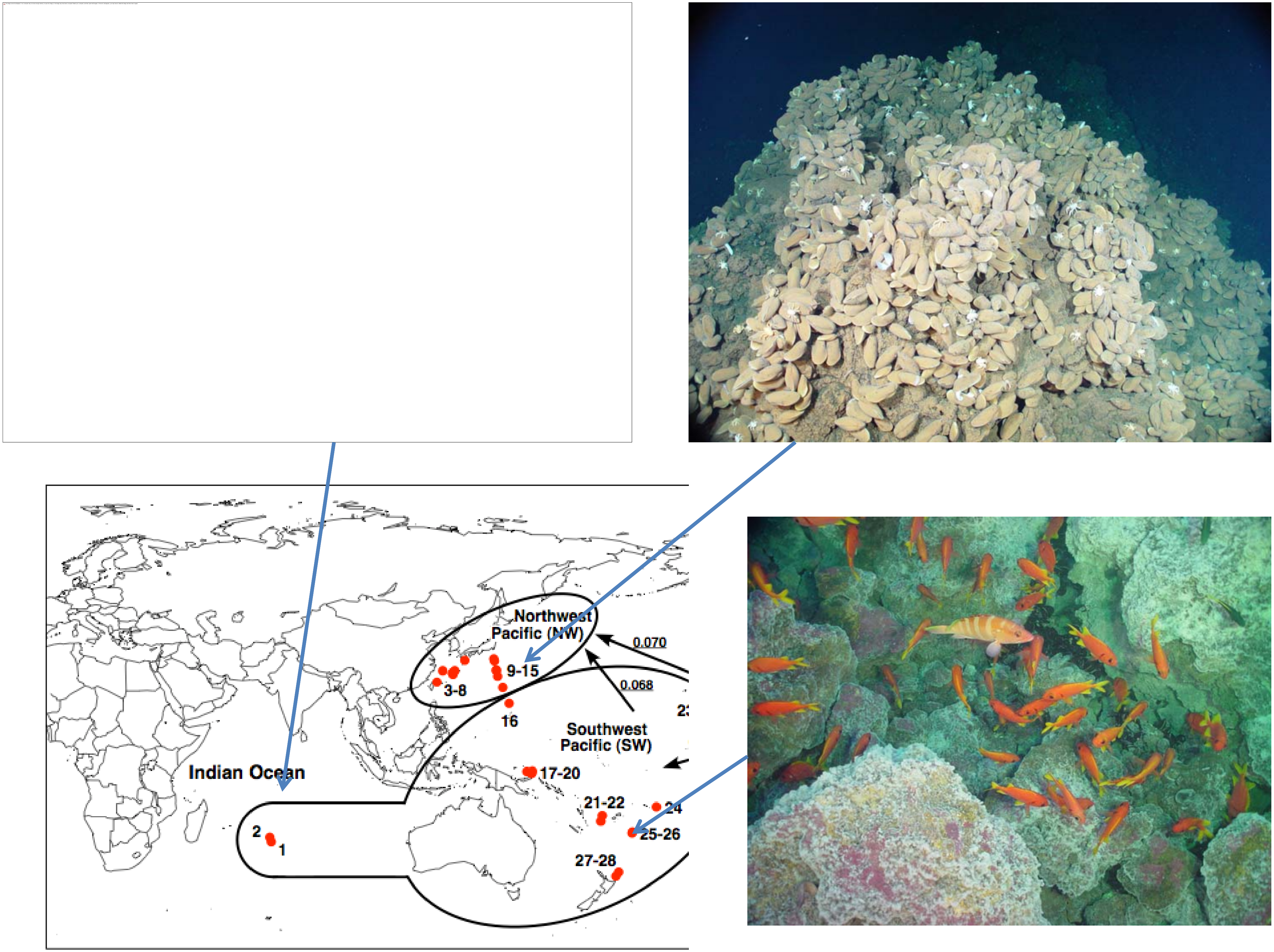
Geographic range of affected species

Uniqueness of local gene pool



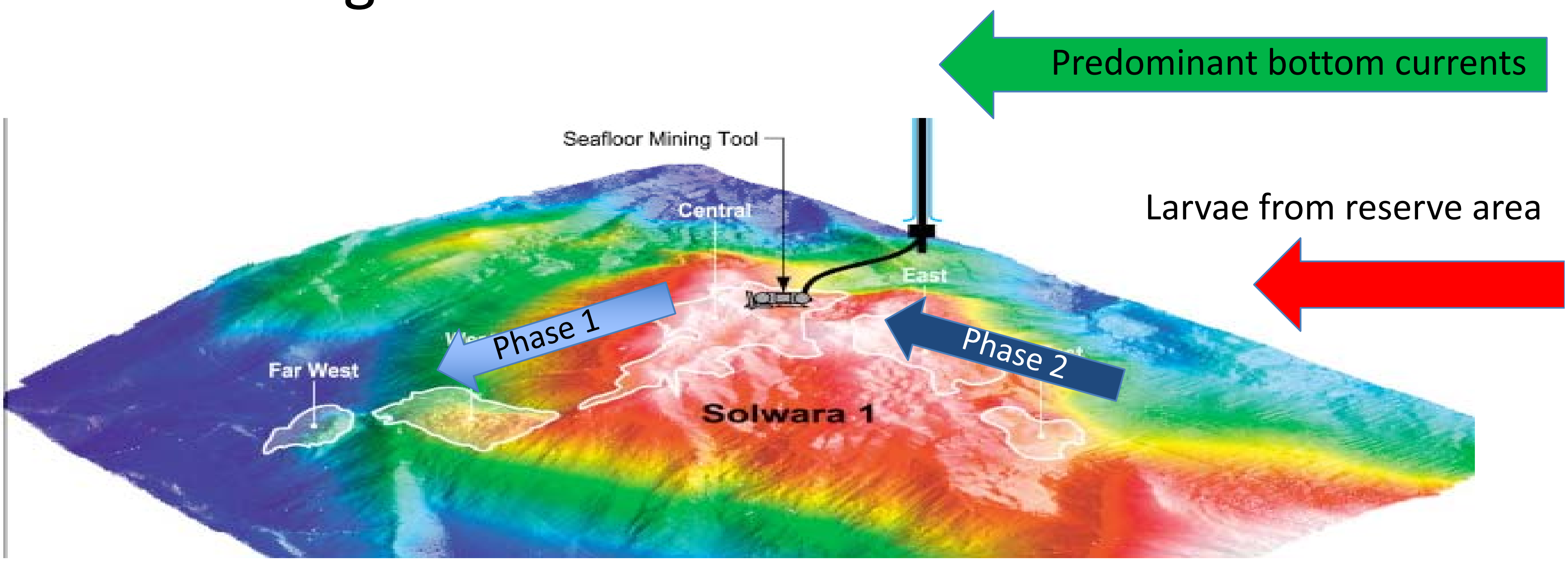
Bacharty et al 2009

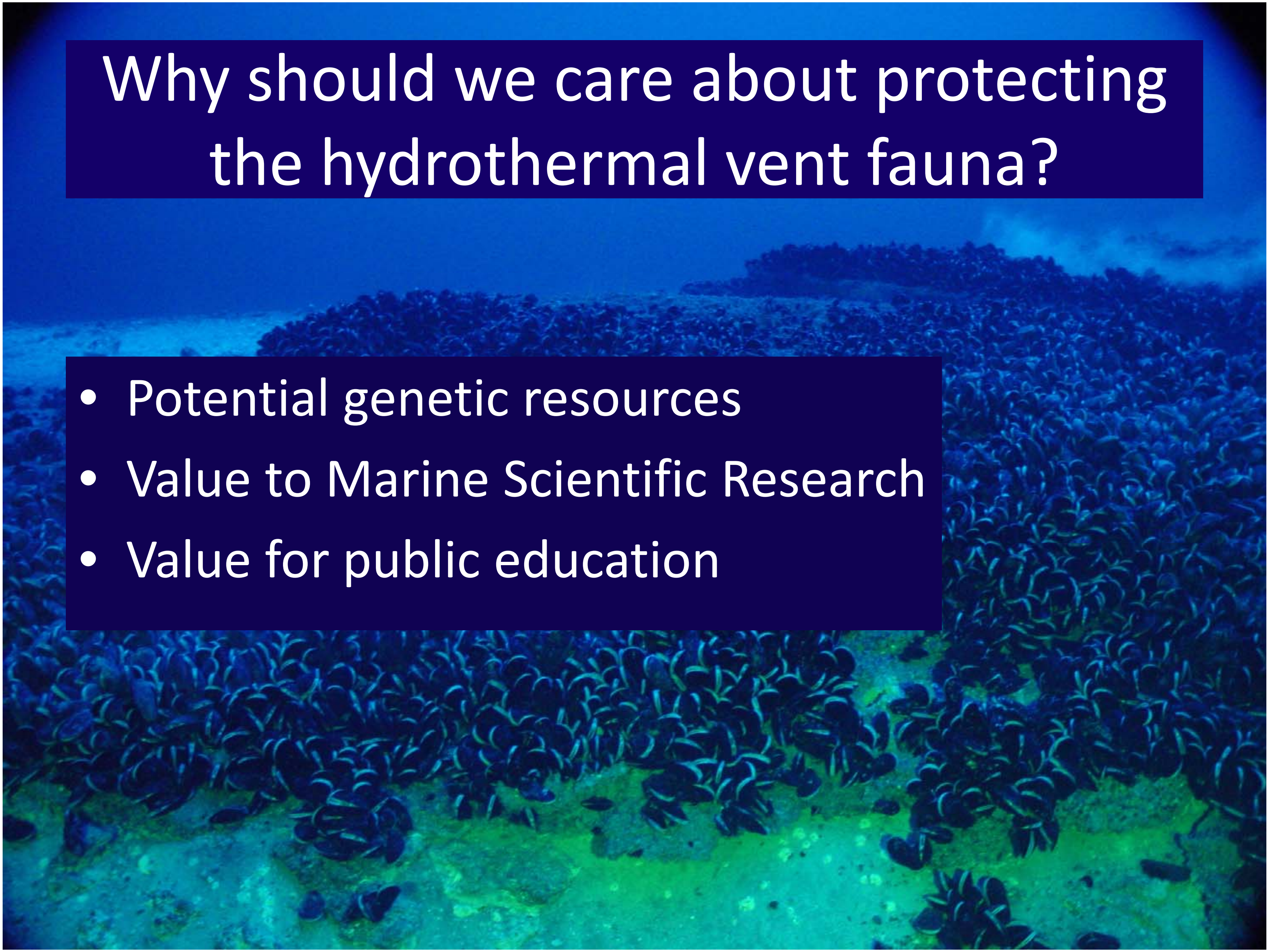



Northwest Pacific (NW)
0.070
0.068
9-15
3-8
16
Southwest Pacific (SW)
Indian Ocean
17-20
21-22
24
25-26
27-28
2
1

Mitigative measures - Reserve Areas

- Larvae can recolonize disturbed sites
- Nautilus - nearby reserve and sequential mineral extraction beginning mid-deposit and working downstream

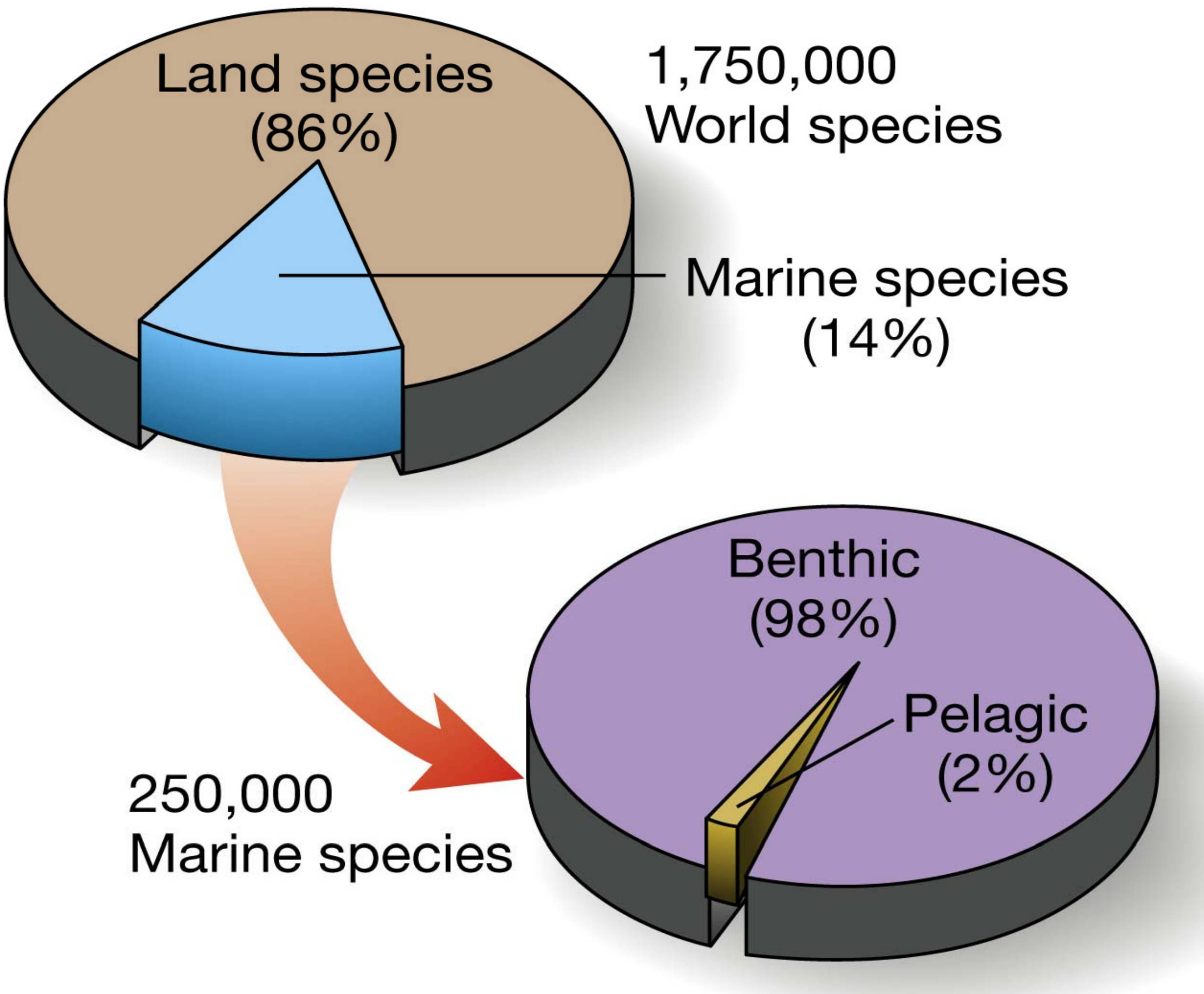



Why should we care about protecting the hydrothermal vent fauna?
• Potential genetic resources
• Value to Marine Scientific Research
• Value for public education

Genetic resources at hydrothermal vents

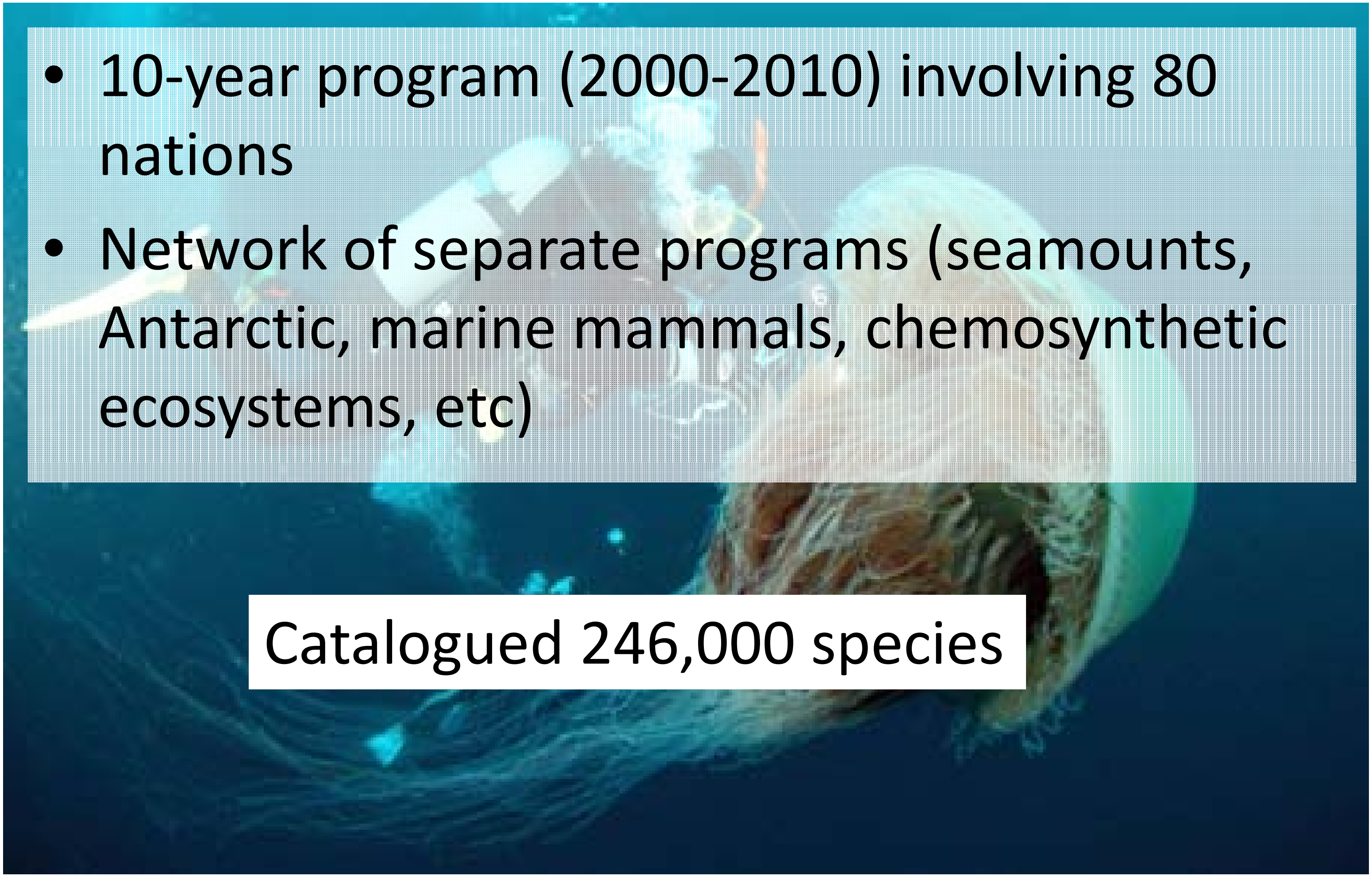
- Small number of animal species
- High, unquantified diversity of microbes
- Large degree of genetic novelty
  - Growth at high temperatures
  - Resistance to heavy metals
  - Unusual symbioses

Biodiversity in the world ocean



Census of Marine Life (CoML)

- 10-year program (2000-2010) involving 80 nations
- Network of separate programs (seamounts, Antarctic, marine mammals, chemosynthetic ecosystems, etc)



Catalogued 246,000 species

Genetic Resources in the Deep Sea – The Promise

*"… a source of new and viable wealth creation"**

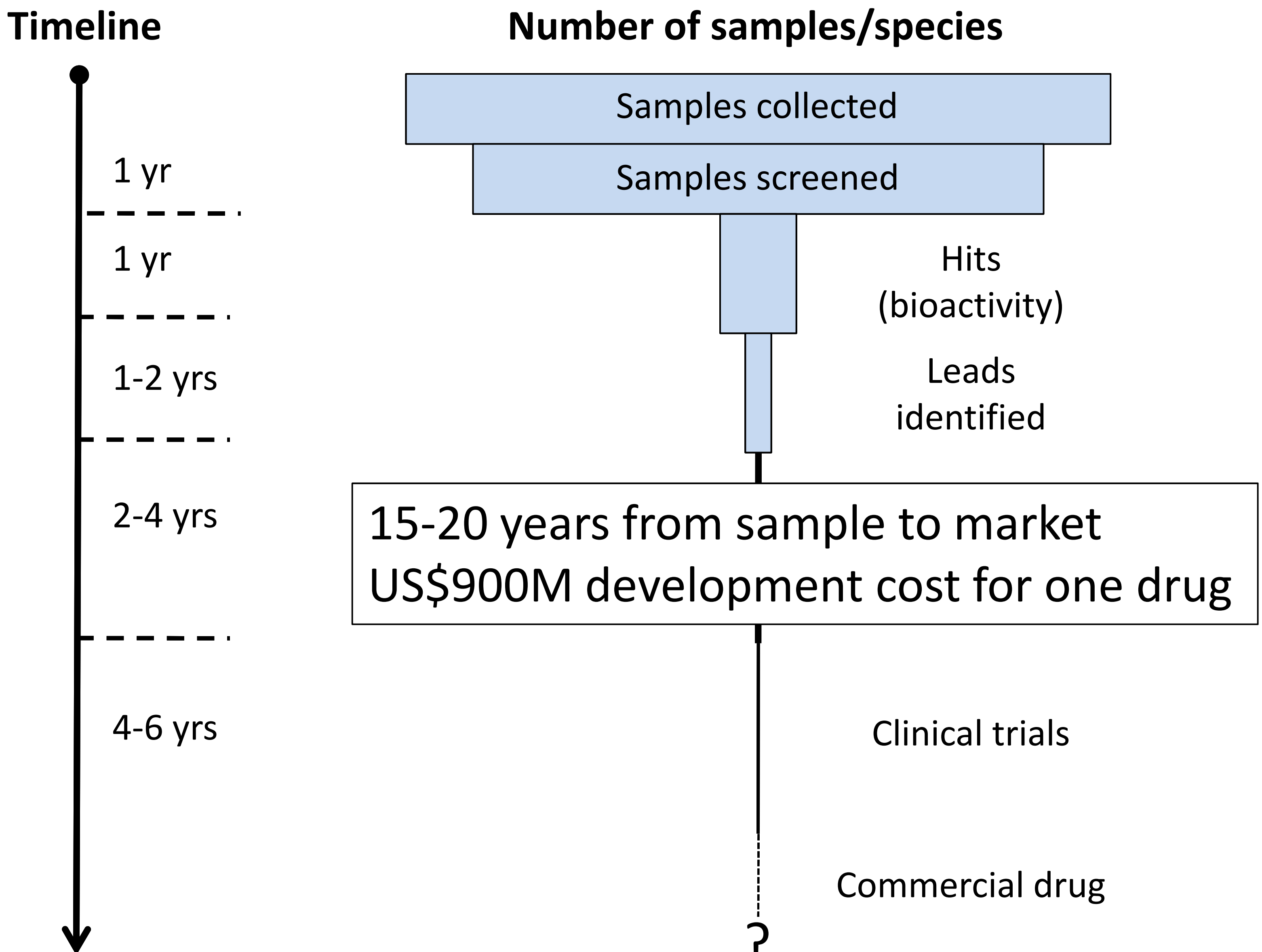
* National strategy on marine bioprospecting, Norway, 2009

Bioprospecting in the deep sea
- The Reality

- Little systematic bioprospecting in deep sea
  – very costly
  – low rate of success on land
    - (1 sample in 250 000 = new drug)*
  – long development time

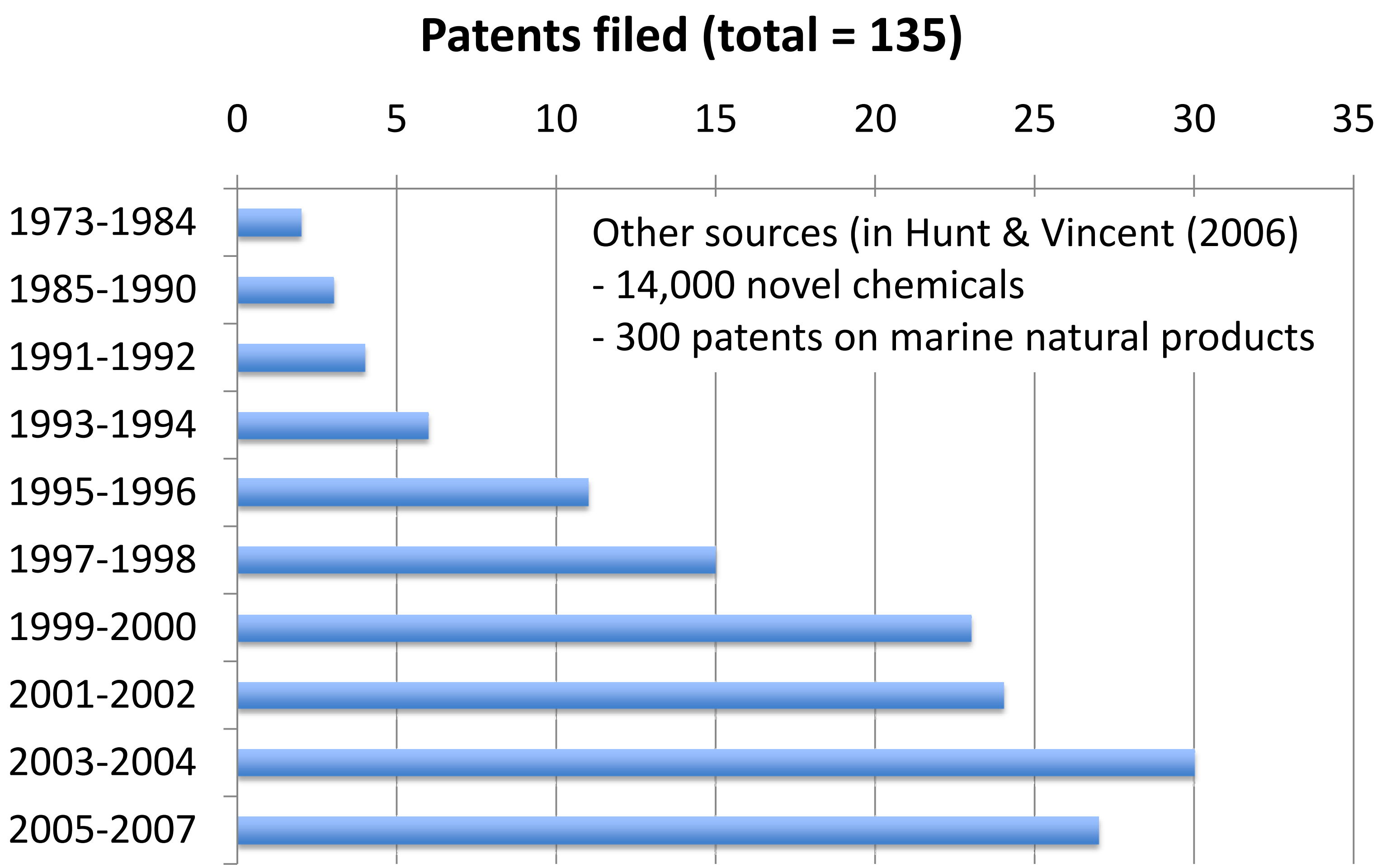
* Nature (1998) 392, 535

Drug discovery and development from natural products



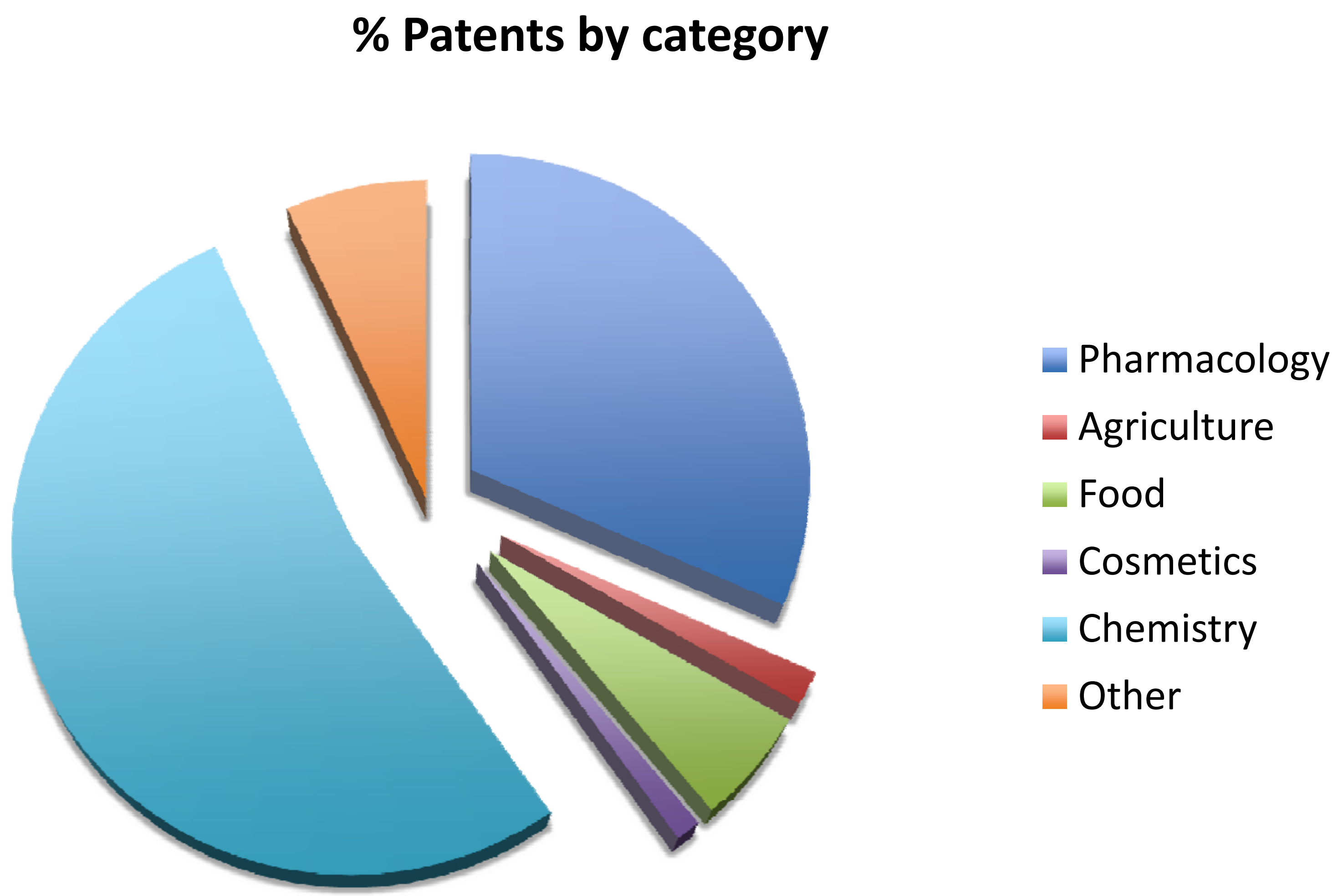
(adapted from Hunt & Vincent (2006) Ambio 35, No. 2)

Marine Genetic Resource Patents



(adapted from Leary et al. (2009) Marine Policy 33, 183-194)

Marine genetic resource patents 1973 - 2007

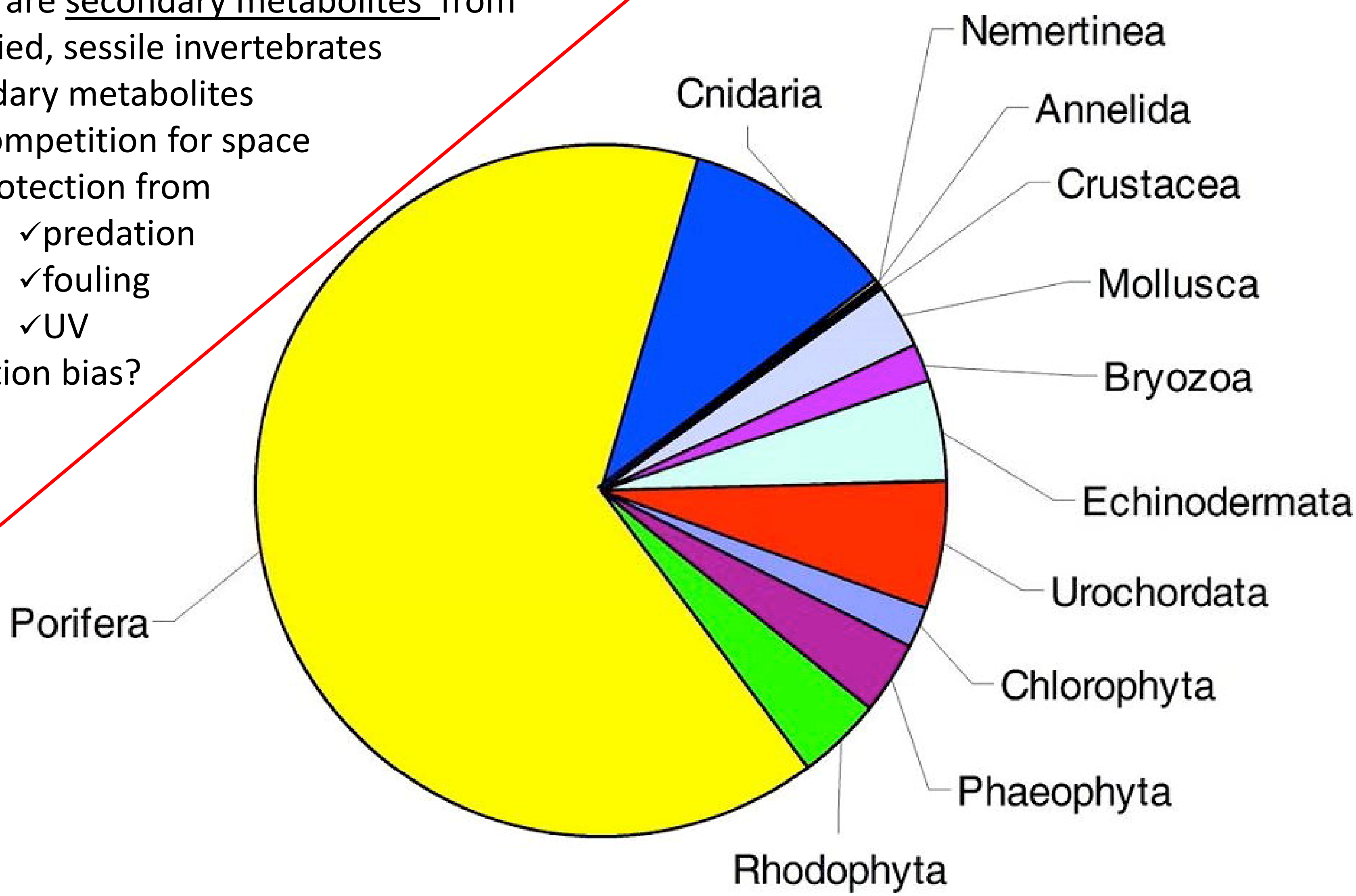


(adapted from Leary et al. (2009) Marine Policy 33, 183-194)

Novel marine compounds grouped by phyla

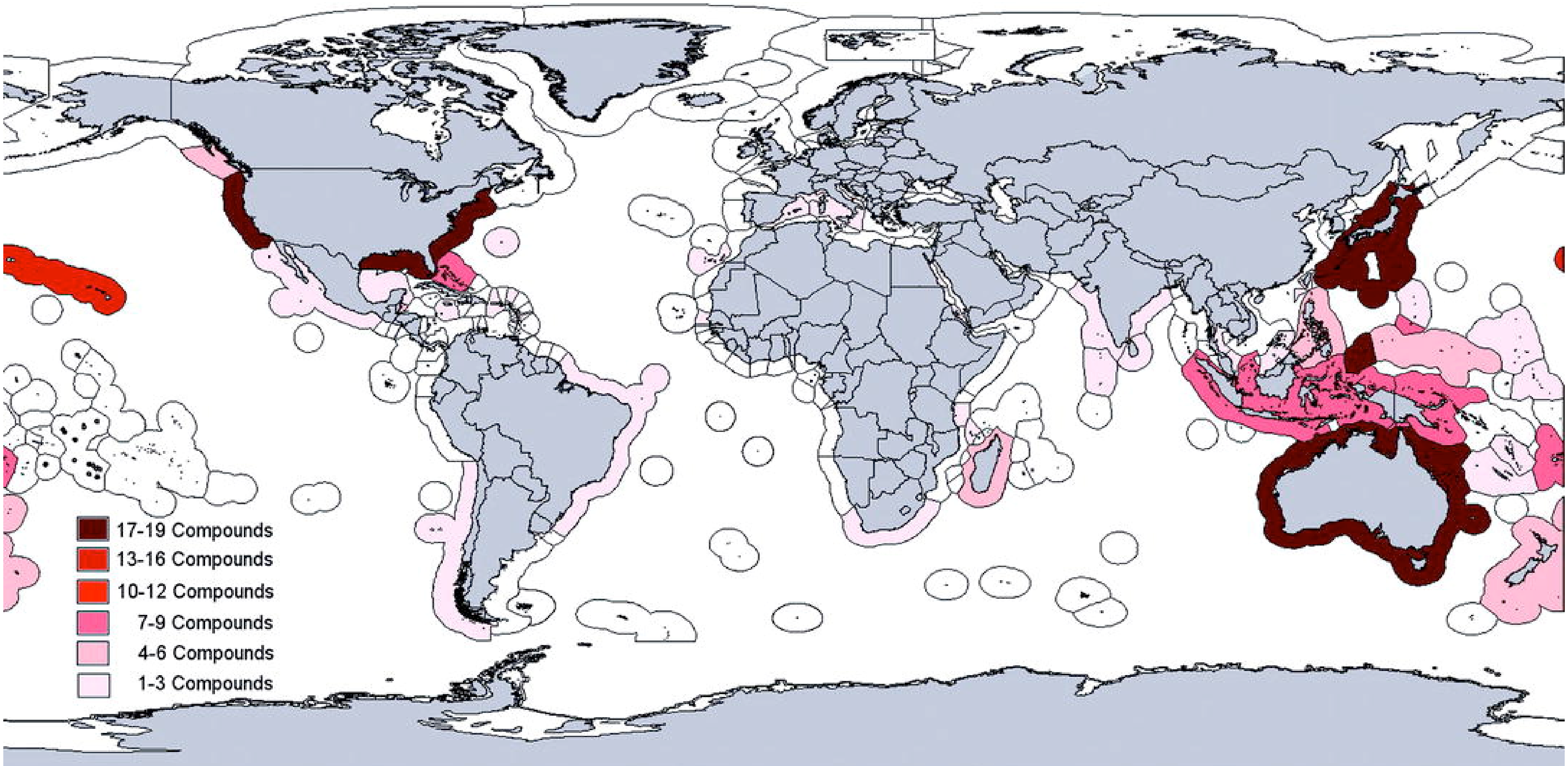
Majority are secondary metabolites from soft-bodied, sessile invertebrates

- Secondary metabolites
  - Competition for space
  - Protection from
    - ✓predation
    - ✓fouling
    - ✓UV
- Collection bias?



(from Hunt & Vincent (2006) Ambio 35, No. 2)

Novel marine compounds in coastal waters



Drugs of marine origin currently in clinical trials (2006)

Drug/Compound	Source Organism	Phyla	Current Supply source	Phase of Clinical Trials	Therapeutic Activity
Prialt (ziconitide, ω-conotoxin MVIIA)	*Conus magus*	Mollusc	Synthetic	III	Pain
Bryostatin 1	*Bugula neritina*	Bryozoan	Wild harvest take (82)	II	Anticancer
Yondelis (ecteinascidin 743)	*Ecteinascidia turbinata*	Urochordate	Semi-synthesis	III	Anticancer
Aplidin (aplidine)	*Aplidium albicans*	Urochordate	Synthetic	II	Anticancer
Kahalalide F	*Elysia rufescens/Bryopsis* sp.	Mollusc/Green Algae	Synthetic	II	Anticancer
Squalamine	*Squalus acanthias*	Chordate	Synthetic	II	Anticancer
KRN7000 (agelasphin derivative)	*Agelas mauritianus*	Sponge	Synthetic	I	Anticancer
Neovastat (Æ-941)	Various "shark" species	Chordate	Wild harvest take	II/III	Anticancer
HTI-286 (hemiasterlin derivative)	*Cymbastella* sp.	Sponge	Synthetic	II	Anticancer
Discodermolide	*Discodermia dissoluta*	Sponge	Synthetic	I	Anticancer
E7389 (halichondrin B derivative)	*Lissodendoryx* sp.	Sponge	Synthetic	I	Anticancer
ES-285 (spisulosine)	*Spisula polynyma*	Mollusc	Wild harvest take (83)	I	Anticancer
NVP-LAQ284 (psammaplin A derivative)	*Psammaplysilla* sp.	Sponge	Synthetic	I	Anticancer
ILX651 (synthatodin, dolastin 15 derivative)	*Dolabella auricularia*	Mollusc	Synthetic	I/II	Anticancer
Cematodin (dolastatin 10 derivative)	*Dolabella auricularia*	Mollusc	Synthetic	I/II	Anticancer
TZT-1027 (dolastatin 10 derivative)	*Dolabella auricularia*	Mollusc	Synthetic	II	Anticancer
IPL-576,092 (contignasterol derative)	*Petrosia contignata*	Sponge	Synthetic	II	Antiasthmatic
IPL-512,602 (IPL-576092 derivative)	*Petrosia contignata*	Sponge	Synthetic	II	Antiasthmatic
IPL-550,260 (IPL-576092 derivative)	*Petrosia contignata*	Sponge	Synthetic	I	Antiasthmatic
GTS-21 (anabasine derivative)	*Pseudopterogorgia elisabethae*	Cnidarian	Synthetic	I	Alzheimer's/ Schizophrenia
CGX-1160 (contulakin G)	*Conus geographus*	Mollusc	Synthetic	I	Pain

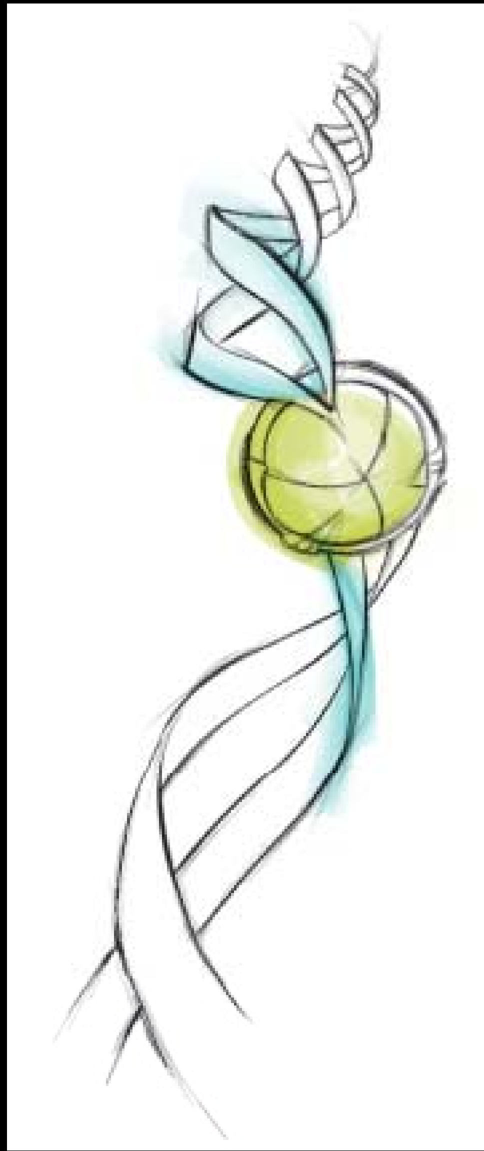
(from Hunt & Vincent (2006) Ambio 35, No. 2)

Yondelis® (trabectedin)

- Marine derived anti-tumoral agent discovered in the colonial tunicate *Ecteinascidia turbinata* and now produced synthetically by PharmaMar.

- Currently approved for treatment of ovarian cancer in 57 countries

Ecteinascidia turbinata

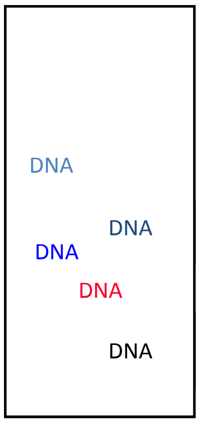


Genetic Resources at Vents – The Promise

Extreme Enzymes

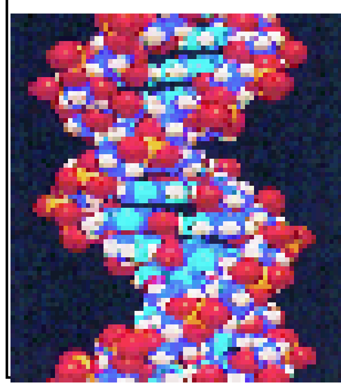
Polymerase enzymes

(taq, Deep Vent$_R$, Pfu)



Polymerase chain reaction(PCR)

>85˚C



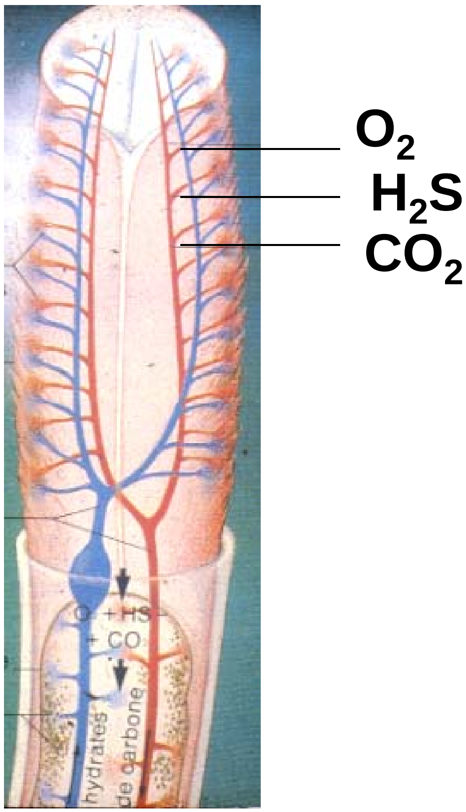
- DNA fingerprinting
- Genome mapping

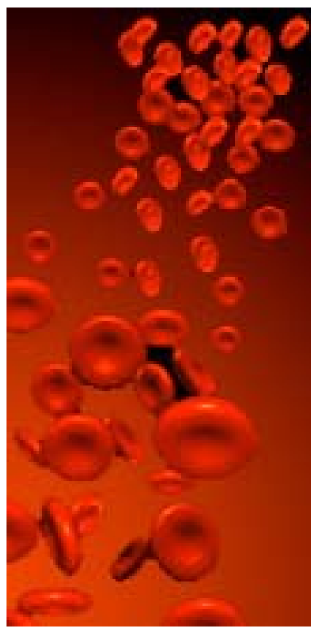
Emerald Pool, Yelllowstone Park
Home of *Thermus aquaticus*

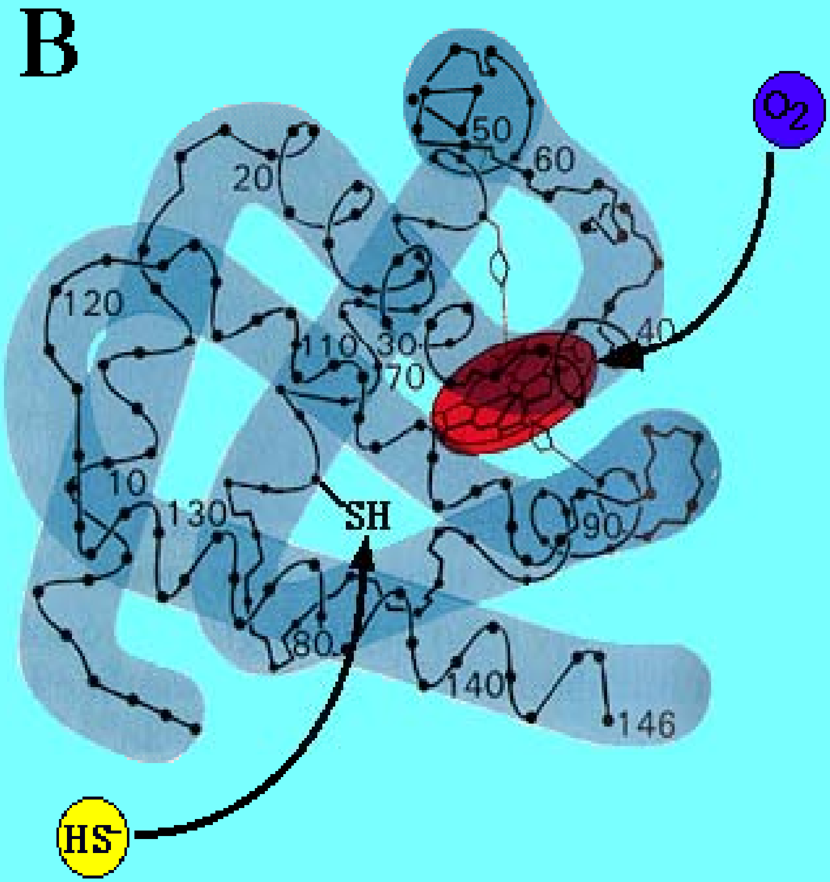
Vent microbe polymerase = 30% of $500M annual global market

Genetic Resources at vents - the promise cont'd

Novel biomolecules







Tube worm haemoglobin

Artificial human blood from marine worms – a promising spin-off from vent research

Blood transfusion problems

Bacteria

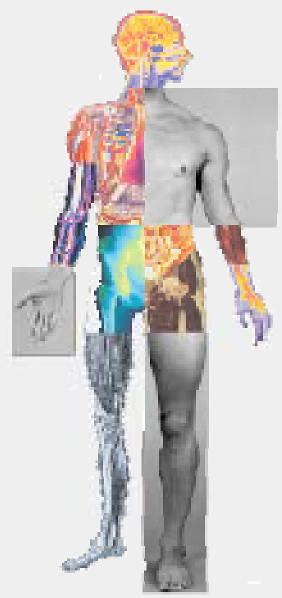
The most transfused infectious agent

Infectious disease

HIV (1/ 3500000), hepatite B
(1/650000), hepatite C(1/3000000)

ABO & Rh System

1 / 30 000 accidents



Known Pathogenes

The tests only detect 5 pathogens

New and emergent pathogens

A risk that we cannot detect

(prions, SRAS, Nil virus, ...)

Limit of the tests

The pathogen incubation period could indentify false negatif

Leucocytes

The residuals lymphocytes and cytokins provock dramatic post-transfusional reactions

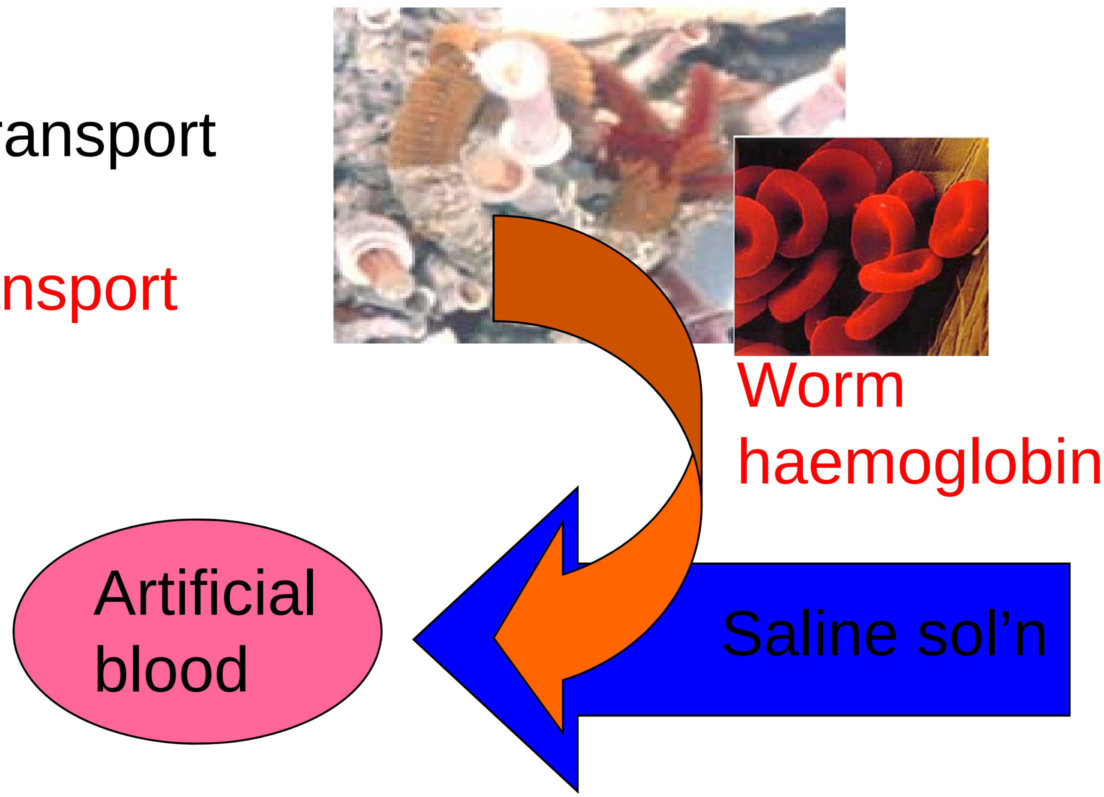
[White book, 2005]

Insufficient amount of oxygen carriers available
Shortage estimated to be 100 million liters / year worldwide
[Winslow et al, 2000]

Artificial human blood from marine worms

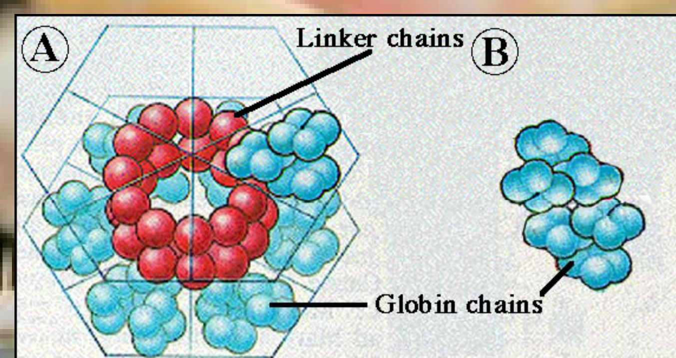
<u>Human blood</u>

- Nutrient/ waste transport
- Immune system
- Gas (O_2/CO_2) transport



Artificial blood from marine worm haemoglobin

- Research began in French laboratory (CNRS-Roscoff) as study of blood from giant vent tubeworm
- Lab developed expertise in study of haemoglobin from marine invertebrates
- Connected with biotechnology industry



Manufacturing of HbAm

Using animals produced under GMP- like conditions

Thawing

⇩

Solid/liquid Extraction by centrifugation

⇩

Hemoglobin in liquid phase

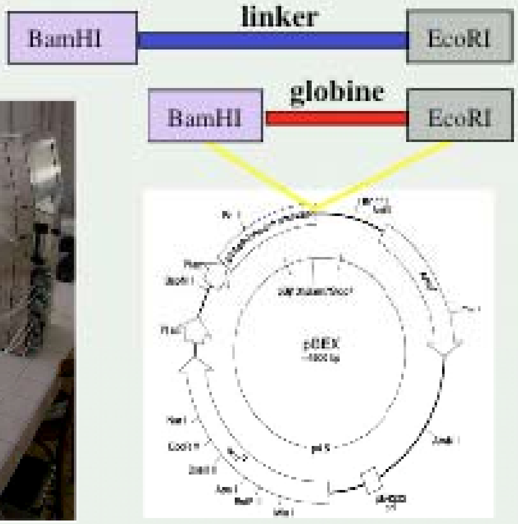
⇩

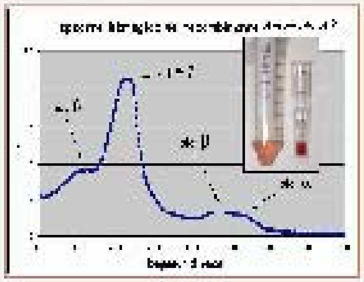
Purification by precipitation, filtration, diafiltration/ultrafiltration and a sterilisation GMP batches

⇩

Control of each bactch: FPLC, HPLC-MS, Functionality, Cytotoxicity

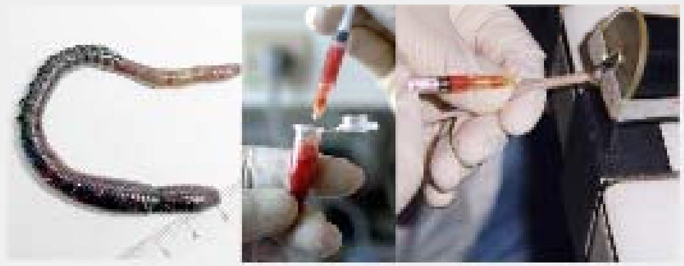
By genes over-expression (Hemarina R&D)



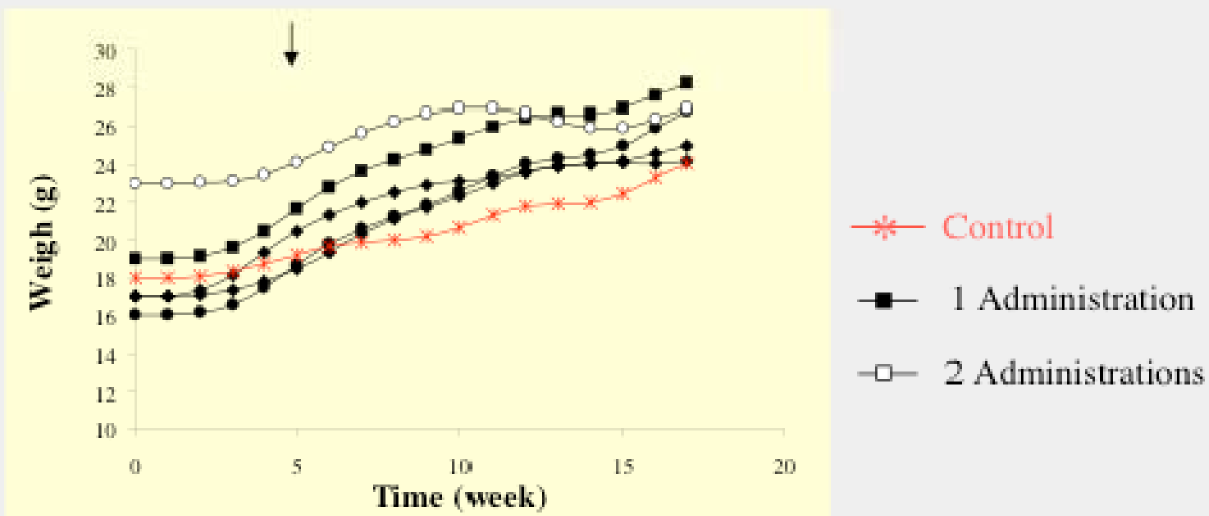


Pre-clinical test on mice –Toxicity-

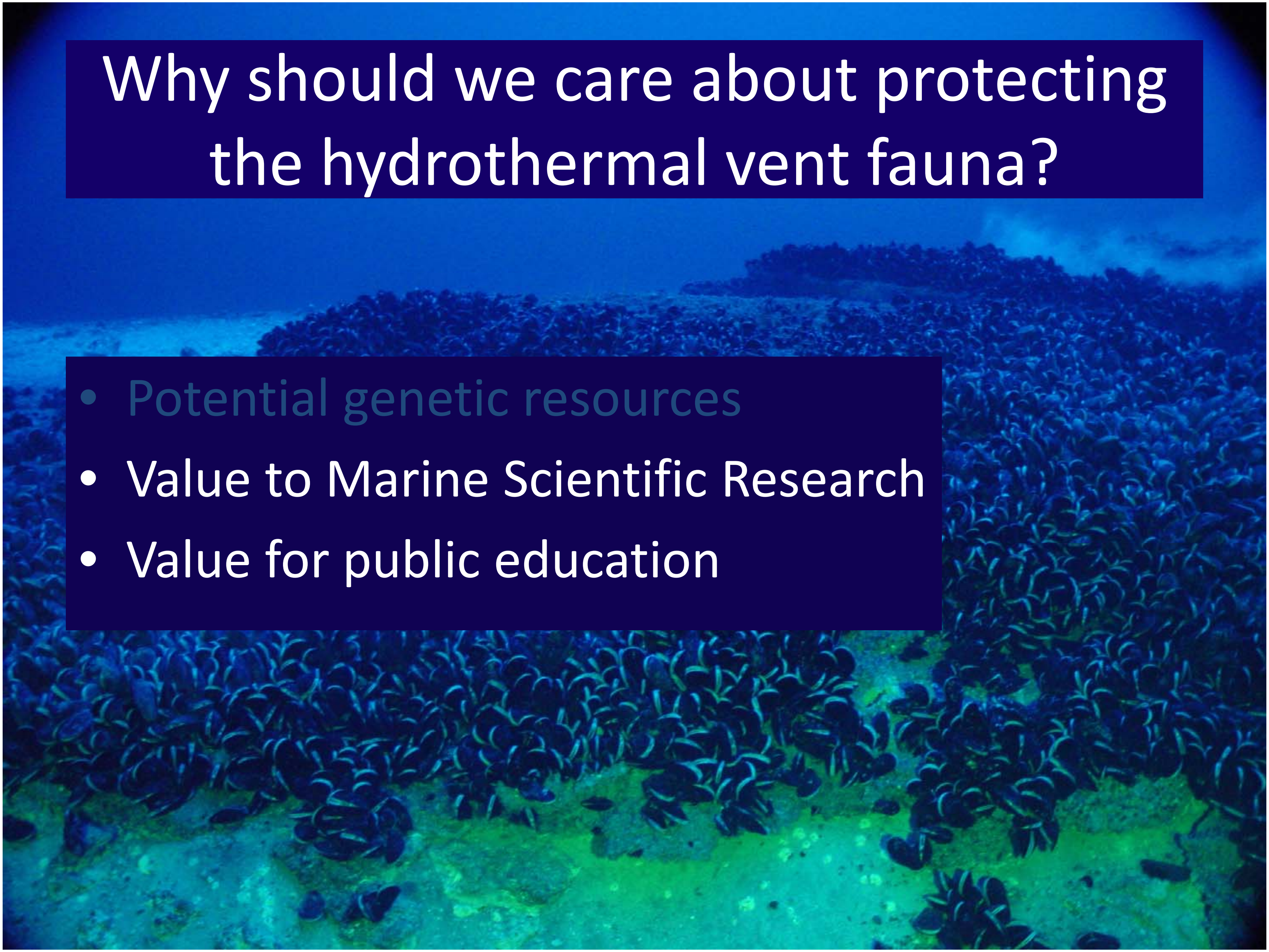
➢ Is HbAm Toxic?



- Mice partially transfused (50 à 25 %) with HbAm



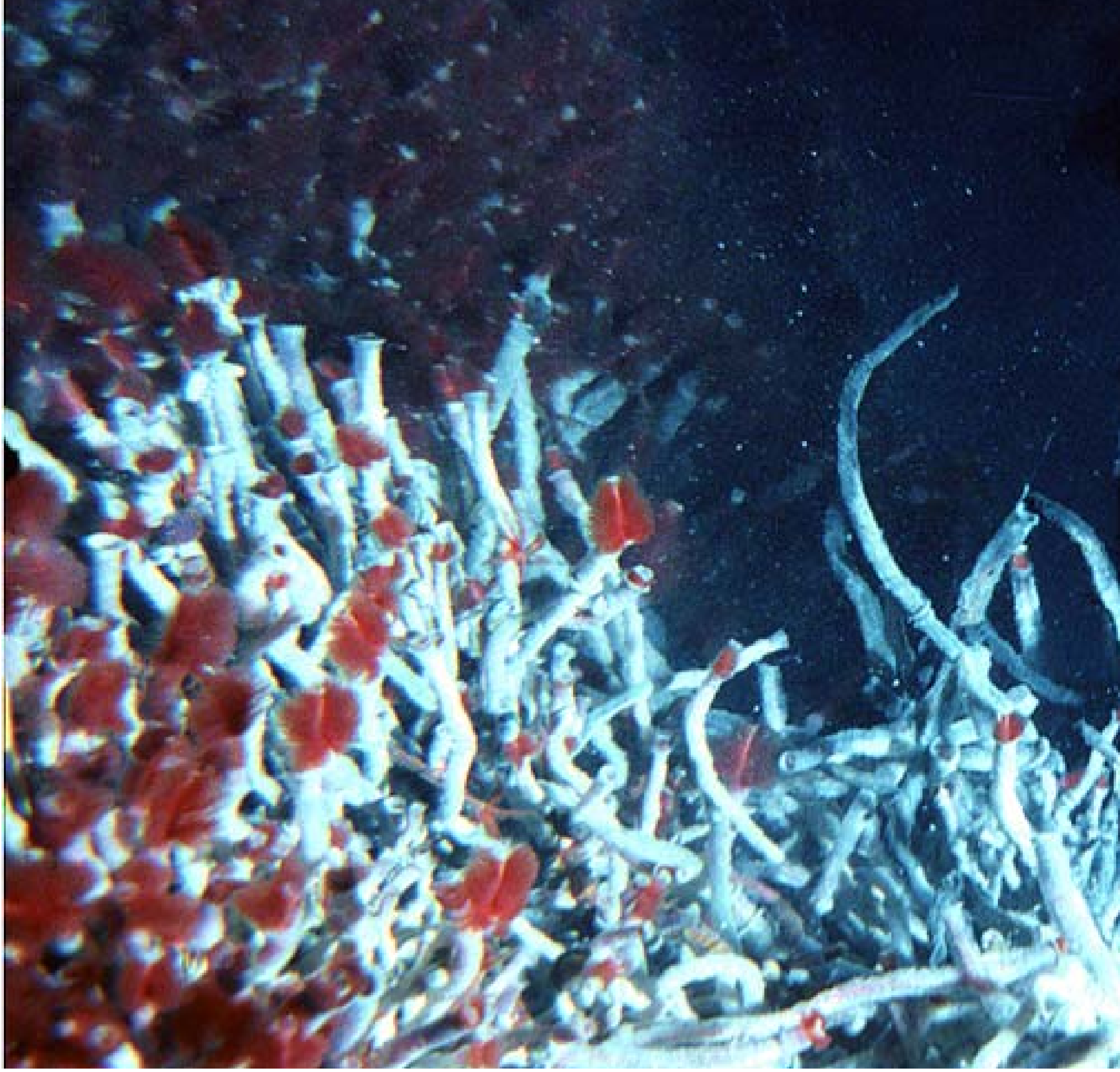
➢ HbAm is not toxic

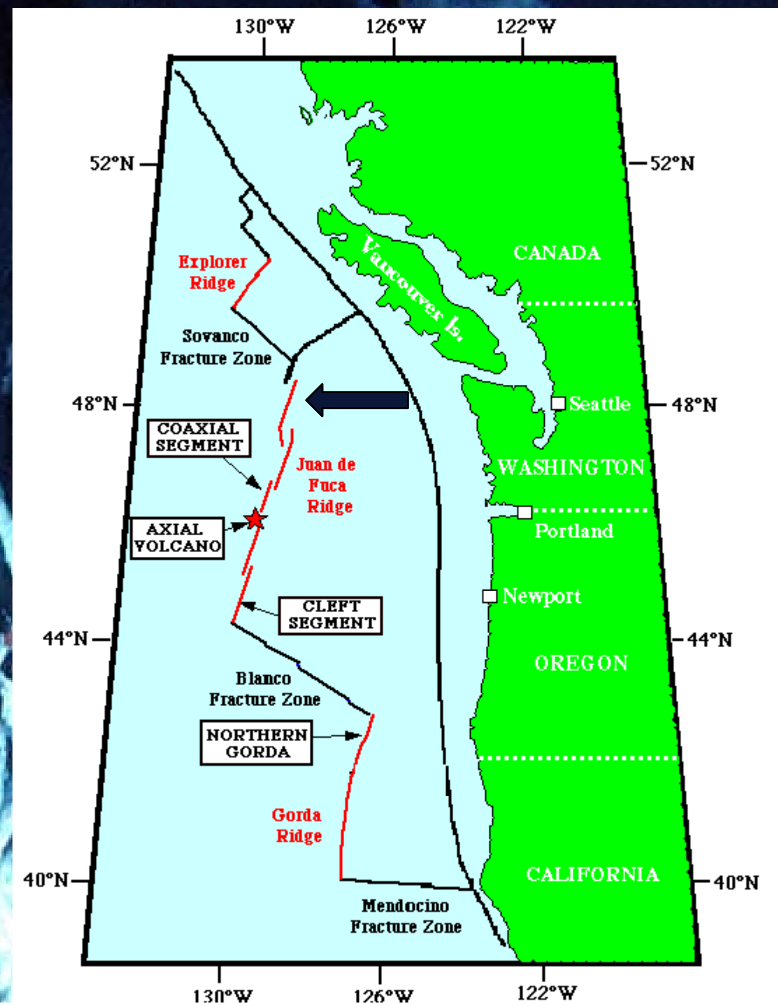

Why should we care about protecting the hydrothermal vent fauna?
• Potential genetic resources
• Value to Marine Scientific Research
• Value for public education

Marine Scientific Research - a major stakeholder at hydrothermal vents

Public education – learning how the Earth works

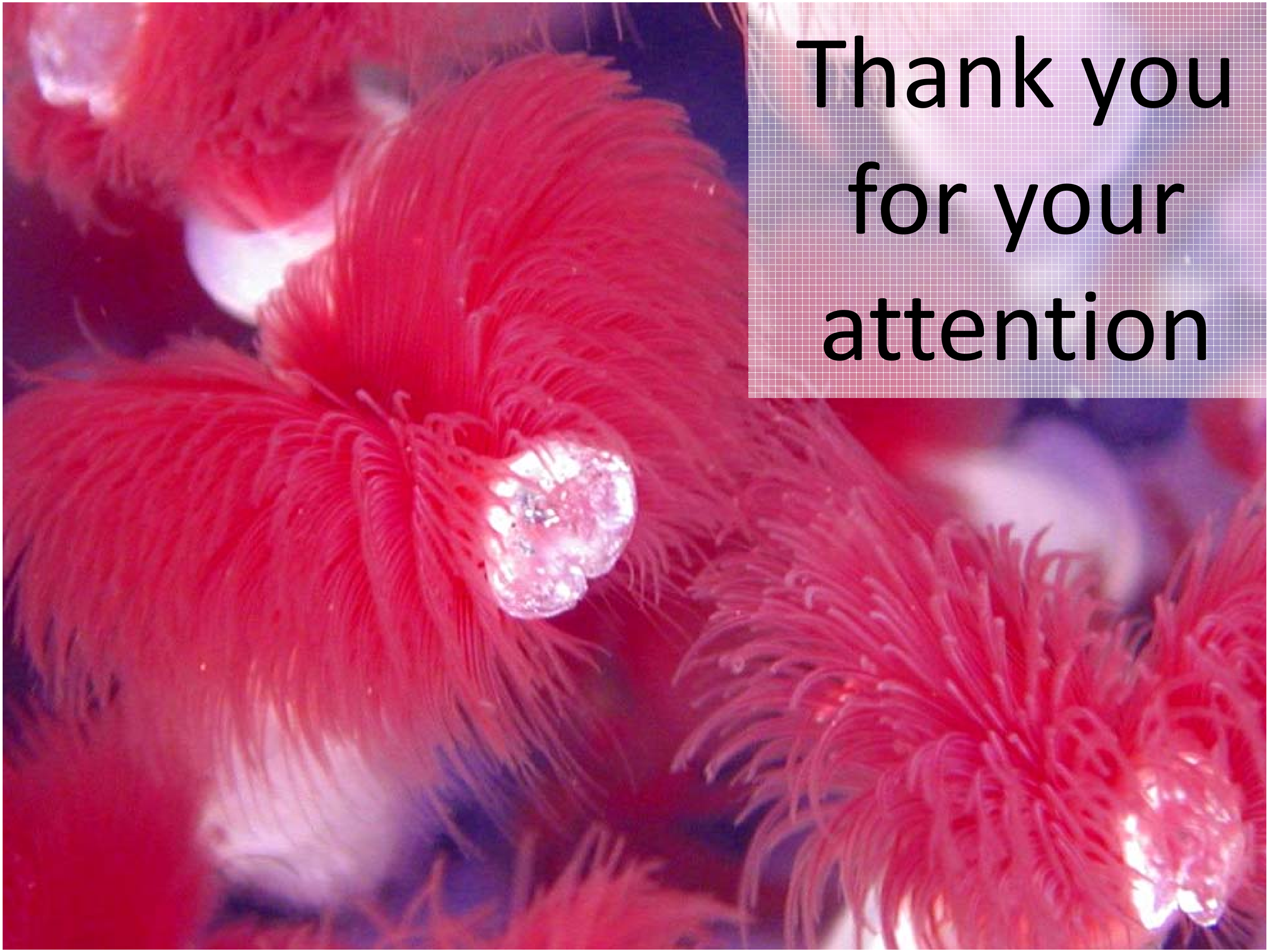
Endeavour Hydrothermal Vents Marine Protected Area – a reserve for scientific research





Monitoring Endeavour vents - NEPTUNE Canada cabled observatory

Juliane Richter, Birte Wagner
GEO Magazine


Thank you for your attention