

Practical Environmental Considerations for Offshore Mining...

A **life** and **death** perspective

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SMD

...aiming to operate in harmony with nature and
in the best interests of the planet and its people.

**But to design and deliver effectively we need unbiased
environmental information about the meeting place of all rivers.**



Contents...

- History of offshore mining on a page
- Environmental headlines
- Real potential effects of underwater mining on the environment
 - Plumes/Turbidity
 - Pollution risk
 - Noise & Vibration
 - Light
 - Loss or damage to habitat
 - Carbon footprint
- Processing and tailings disposal
- Effect of key offshore industrial activity on the environment
- Takeaway points

Practical and
comparative
perspective

Subsea mining...

History...

- Subsea mines for **lead** and **zinc** in ancient Greece at Laurium
- **Coal** was first mined offshore in 1575 in Scotland!
- Extensive coal workings off the Cumbrian and Northumberland coastlines
- Extensive coal workings off Japan
- 30 years of **Amber** mining from 1860 in the Baltic Sea
- **Tin** and **copper** has been mined underneath the Cornish coast
- Blasting and underwater dredging of **Barite** off Alaska
- **Polymetallic nodules** have been mined/dredged in the Bay of Finland
- Subsea **iron** ore off Finland and off Elba island, Italy and Cockatoo Island, NW Australia

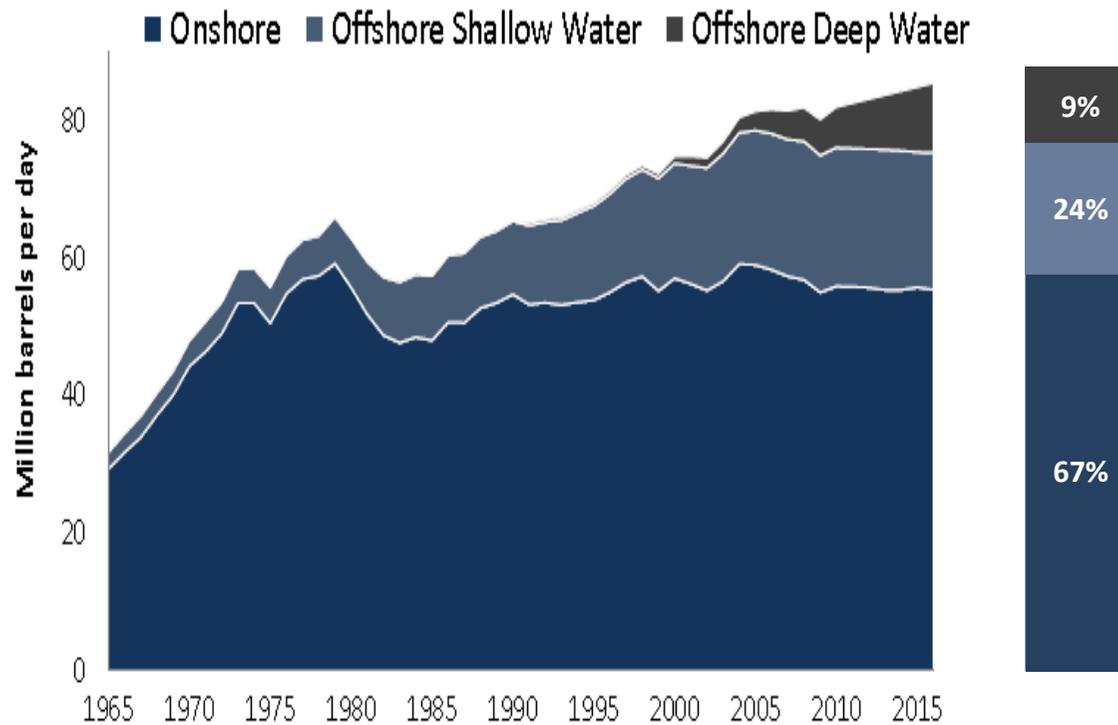
Today... **>150 million tonnes per annum**

- Placer deposits of **diamonds**, tin, **gold**, **magnetite** and various construction **gravels** are being mined/dredged at various offshore locations around the world
- This is being done in shallow waters with semi-conventional dredging equipment and using seabed crawlers in the case of diamonds

Increase in offshore mineral sourcing...

Onshore crude oil production has plateaued and offshore has increased to approximately a third of supply (*source: Infield Systems Limited*)...

Onshore vs. Offshore Oil Production



A similar gradual shift offshore is likely for other minerals!

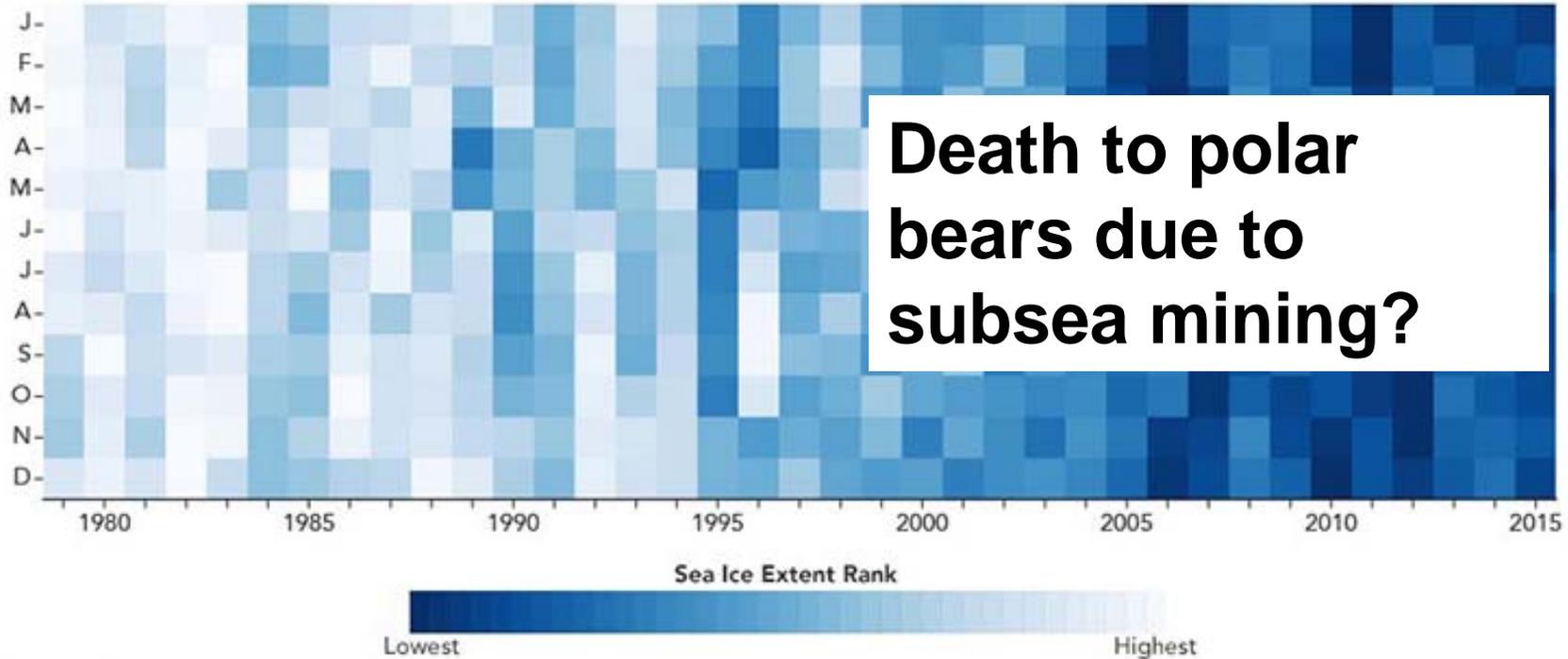
Opposition to mining...

News headline...

Subsea mining threat to life in polar regions

(with a link to articles on shrinking ice caps)

Arctic...



NASA Earth Observatory/Joshua Stevens

Subsea mining in the Arctic...

These days, typically 150Mt hard minerals mined per annum offshore...

But not in the Arctic Circle.

There are some land mines in Arctic regions.

A small amount of subsea mining in the Bering Sea – south of the Arctic circle.

There may be some ice-breaker vessels associated with supplies and ore transportation.

But as far as I can ascertain, nobody is commercially mining significant volumes of ice.



I cannot find any relationship between subsea mining volumes and the decrease of Arctic ice volumes

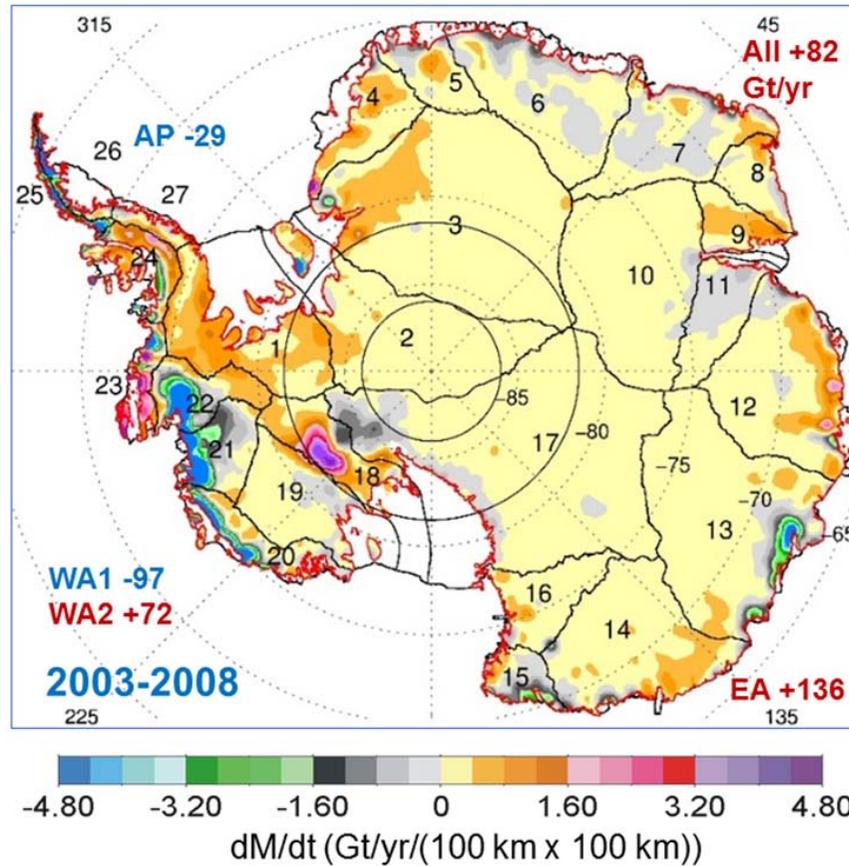
Antarctic...



GLOBAL CLIMATE CHANGE
Vital Signs of the Planet

NEWS | November 6, 2015

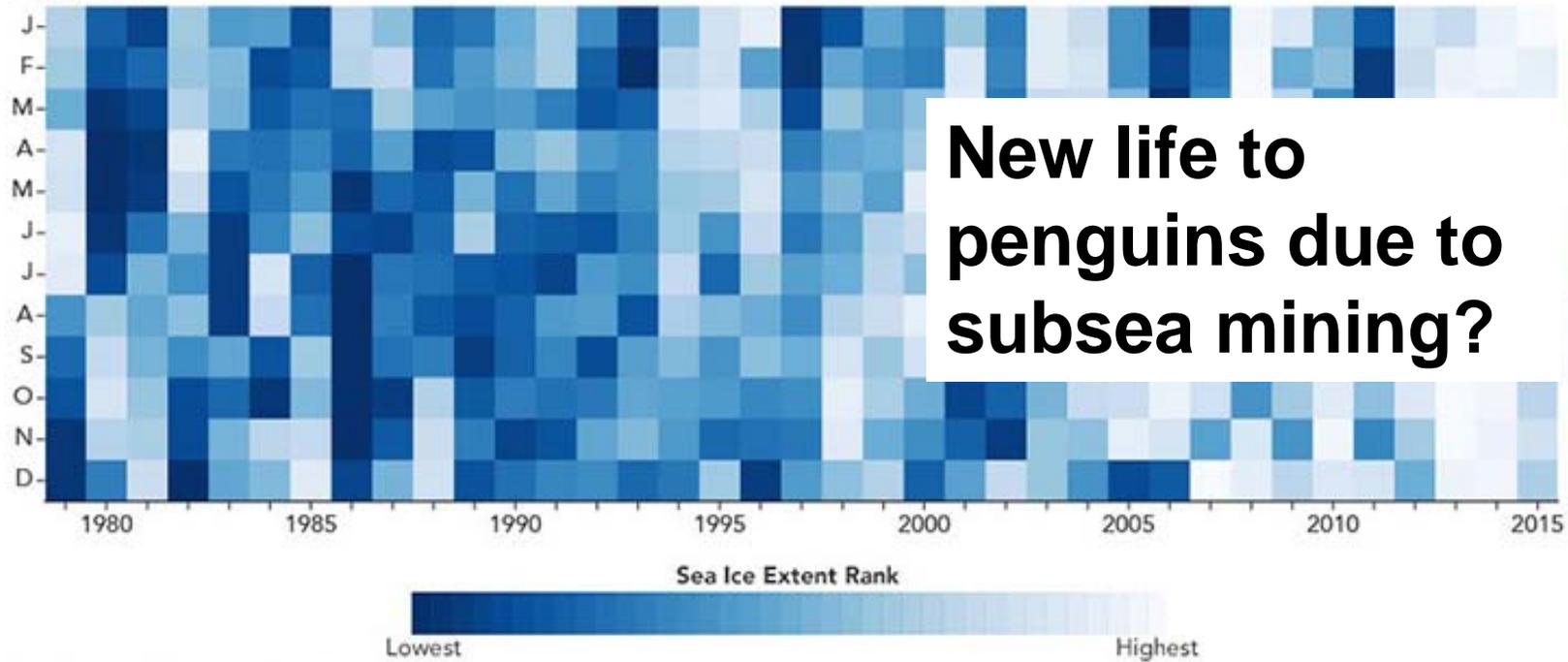
Study: Mass gains of Antarctic ice sheet greater than losses



Antarctic...



Antarctic



New life to penguins due to subsea mining?

NASA Earth Observatory/Joshua Stevens

Subsea mining in the Antarctic...

These days, typically 150Mt hard minerals mined per annum

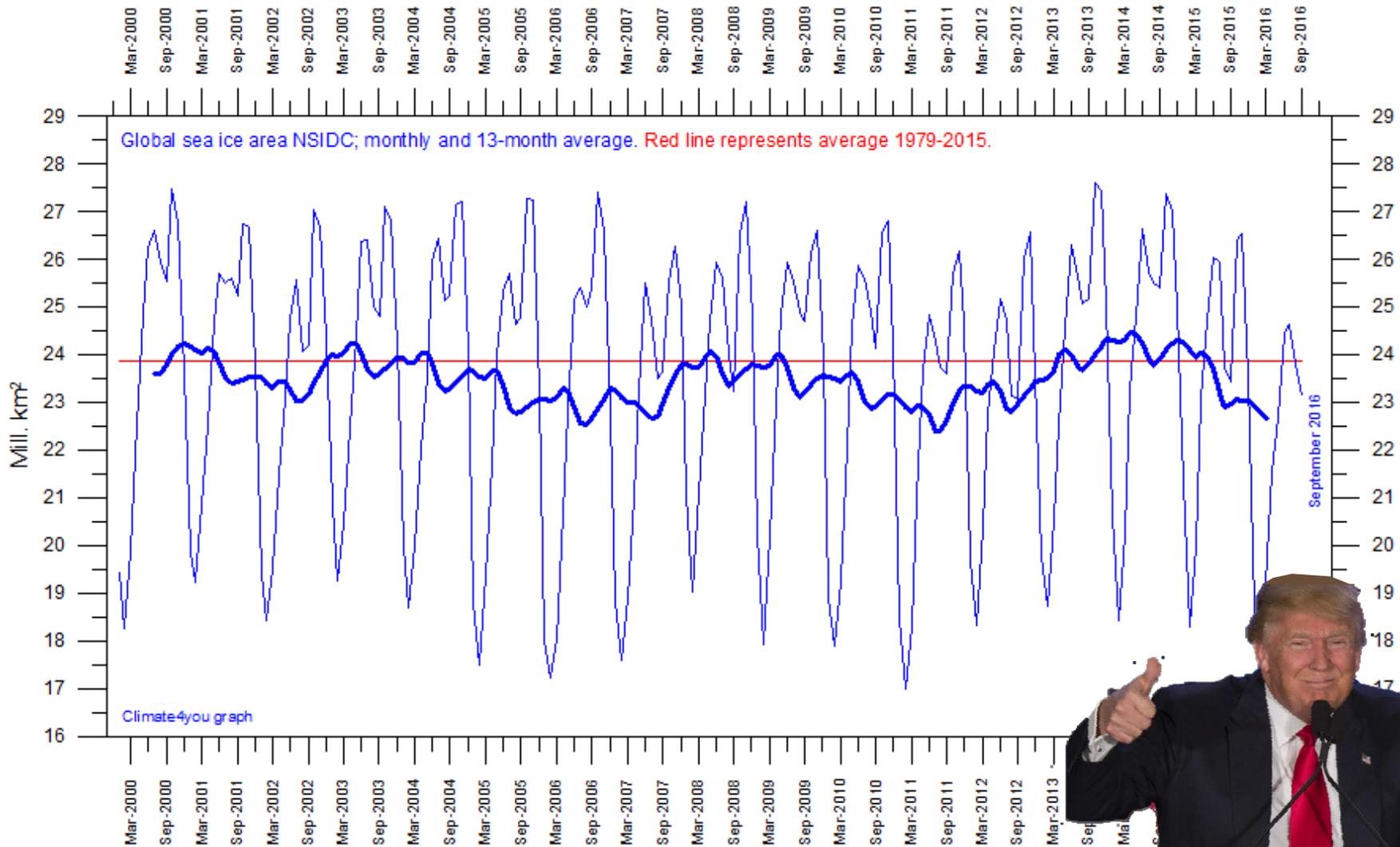
I cannot find any relationship between subsea mining volumes and the nett **increase of Antarctic ice**

There has never been any commercial mining in Antarctica.

There are no current plans to mine Antarctica and mining is currently completely banned by the Antarctic Treaty.

There are no known future plans by any of the Antarctic Treaty nations to reverse this decision.

Total global sea ice...



Onshore...

Coal plant threatens Bengal tiger ecosystem...



Royal Bengal tiger (Photo: Dibyendu Ash / Wikimedia Commons).

Nearshore...

The Great Barrier Reef and the coal mine that could kill it



Deeper waters...

...or teeming with both life and death?



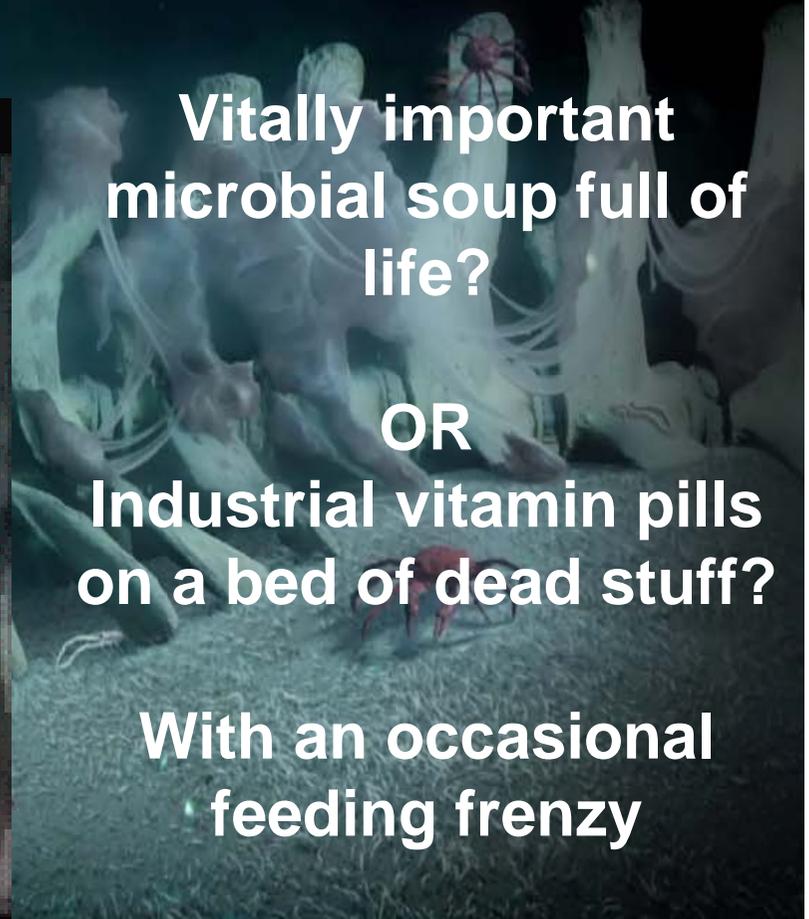
Manganese nodules on a siliceous ooze...

Vitally important microbial soup full of life?

OR

Industrial vitamin pills on a bed of dead stuff?

With an occasional feeding frenzy



SMS deposits...

Hot vents, teeming with life...



Extreme shrimp may hold clues to
alien life... NASA Jet Propulsion Laboratories

The same applies to any living organism anywhere on the planet.

Equally these shrimp may hold clues to alien death...

...on the next extinction/eruption event.

And in any case, anyone trying to mine a hot vent would melt their machine.

Abyssal plane versus land mineral deposits...

- A variety of interesting fauna exist at sea or inland – life is everywhere
- You can find plenty of pictures like this, in articles claiming the area is “teeming with life” ...

Nodules on the abyssal plains



Rain forest

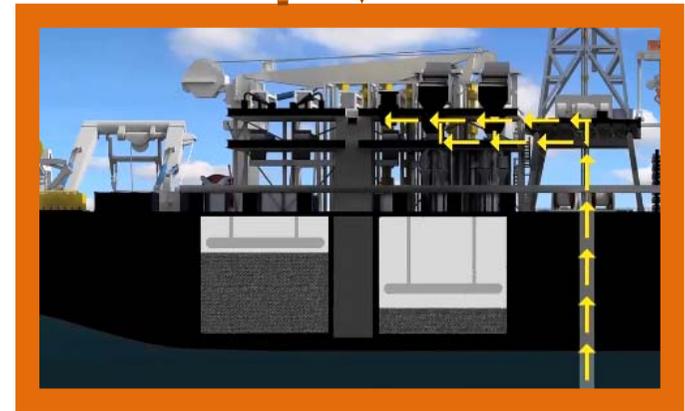
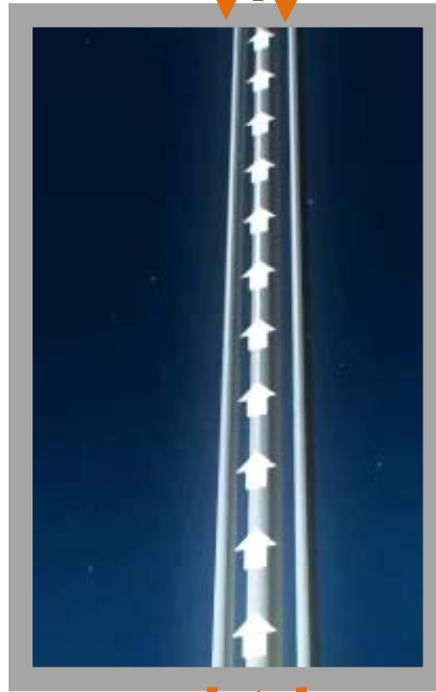
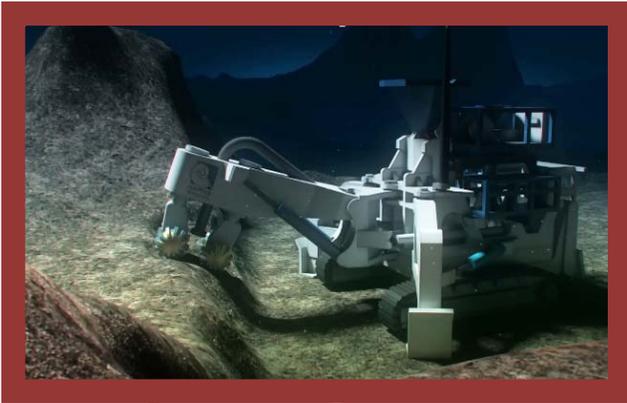


- But these are more representative of reality
- So what is the comparative species density – perhaps by size classification – compared to a land desert or an equatorial rain forest?

Turbidity potential from mining...

Transport to vessel

Cut and/or collect

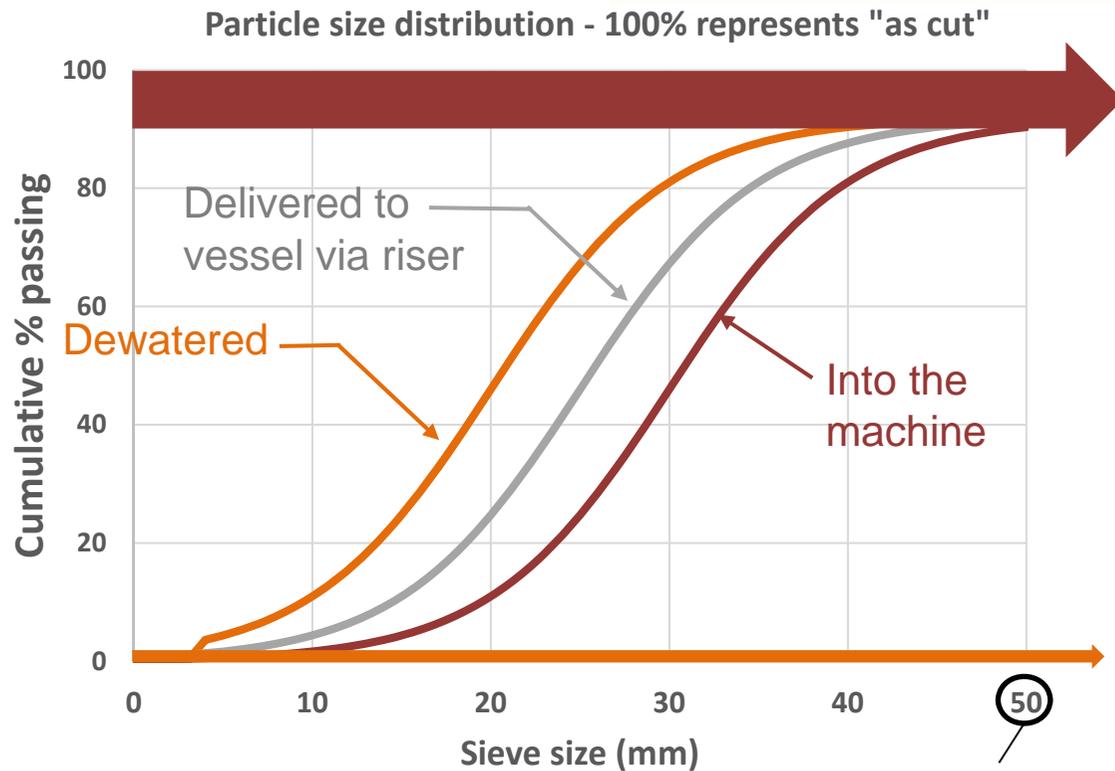


Dewater

Spillage/oversize

Dump valve operation?

Particle sizes, sources and destinations...



Spillage/oversize

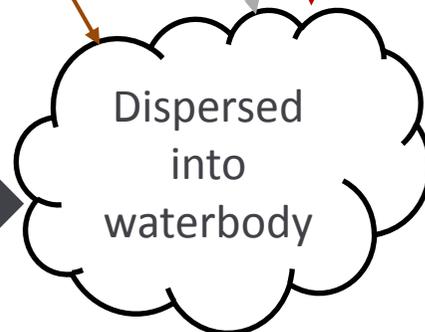
- Spillage falling out of path of machine
 - Oversize scalped off by knife plate
 - Minor amount of fine particles remaining uncollected
- Mined on next machine pass**

▪ Dump valve operation?

▪ Sub 10 micron in return water from dewatering plant



50mm
Grill aperture on machine



Natural turbidity in the oceans...



Black Smokers
(iron mono-sulphide)



White Smokers
(more barium, calcium and silicon)



Natural turbidity in the oceans...



Benthic storm



Volcanic eruption off Hawaii



Subsea volcanic plume



Large mammal disturbance

Natural turbidity in the oceans...



Dust cloud from the Sahara – about the size of Spain



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Natural turbidity in the oceans...



River and creek discharge



Coastal erosion



Of course, some areas of the ocean are more turbid than others



Species Resilience...

- Some ocean creatures are clearly sensitive to changes in the ocean environment
- But many of the creatures that live in the deep sea are extremely resilient – classed as “extremophiles”. Some are “polyextremophiles” that can cope with a variety of harsh environments...
 - No sunlight
 - No oxygen
 - Extreme pressure
 - Extreme temperature ranges
 - High acidity
- In comparison, if you parked a subsea vehicle over an active vent - it wouldn't last very long
- Clearly, any subsea mining machine needs to be designed with the working environment in mind

Practical points...

- A machine designer will aim to minimise the amount of fine particles generated wherever possible...
 - To avoid environmental issues
 - To avoid re-handling of material
 - To improve visibility in the vicinity of the mining machine
 - To avoid loss of “gold-dust”
- Active vents (where polyextremophiles congregate) should be avoided in the mine plan
 - To avoid melting or corrosion of critical machine components

Measures to minimise turbidity generation...

Lots of options depending on the type of mining area...

- Design excavation tools so that the excavation zone is as close as possible to the suction influence zone
- Increase suction power
- Test capture rates by combination of CFD and scale testing
- If deposit topography allows, cut (or collect) underneath machine and shroud the excavation/suction zone
- Use water-jet curtains
- Import non-turbid water to working area
- Use surveillance, navigation and positioning equipment that can cope with turbidity
- Use pre-programmed robotic machine moves that don't depend on visibility
- Use enclosed on-board crusher

Pollution risk...

Pollution from mining machine's oils & greases?

- The majority of the systems on-board the machines are **electrically driven**. Those that aren't are sealed and contain very low volumes of oil and grease - of an approved biodegradable type.
- Similar risk as any large work-class or trenching ROV

Pollution from production support vessel?

- Same risks as any offshore production vessel from any industry

Pollution from ore transportation barges?

- Same risks as any offshore mineral transportation vessel
- Perhaps less risk than oil tankers

Other potential impacts

- Machines are designed to **minimise vibration and noise**. Light is required to provide visibility and assist navigation

Noise/sound/vibration...

- FISH
- AMPHIBIANS
- BIRDS
- HUMANS

Biggest octave range

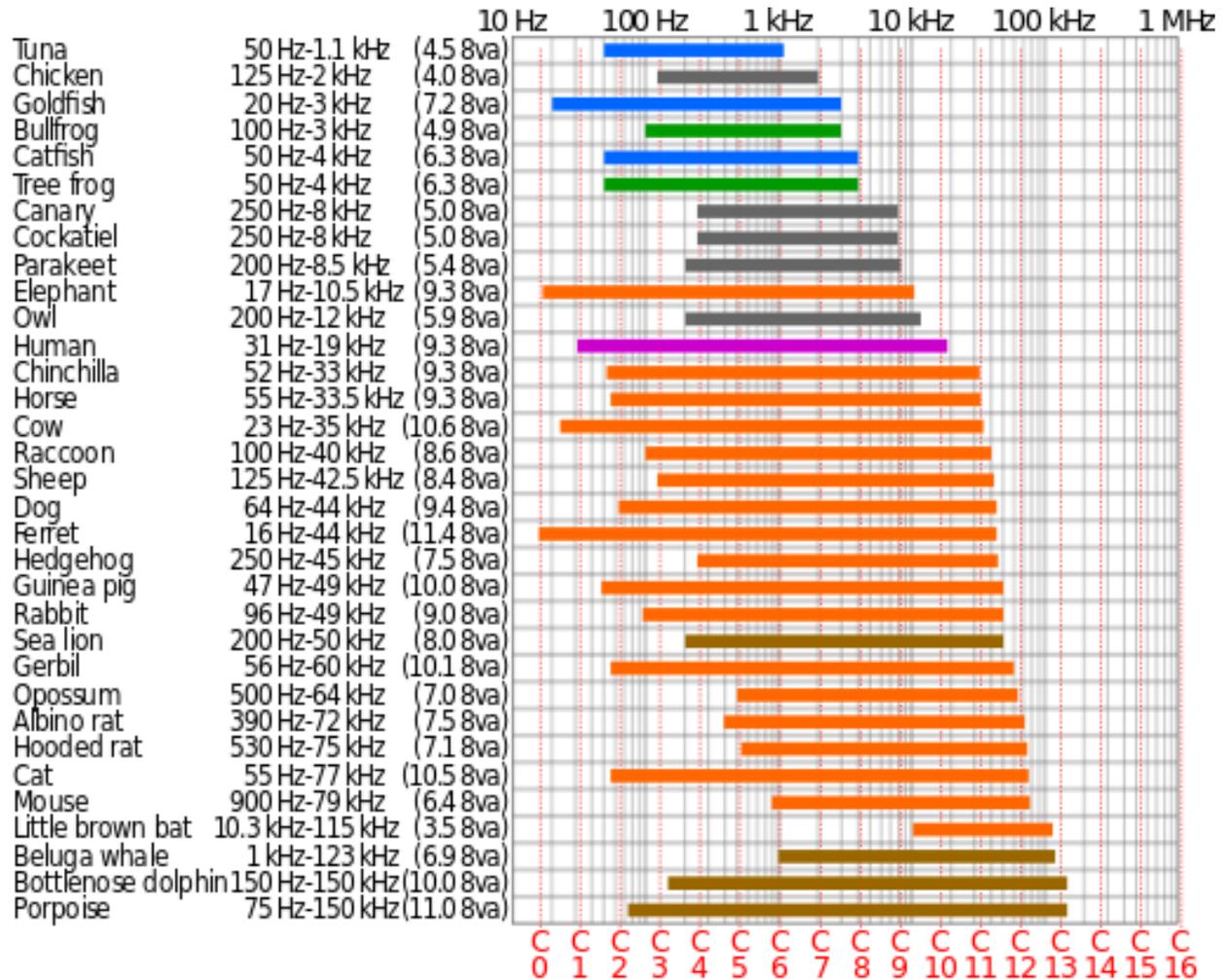


Lowest frequency perception

■ LAND MAMMALS

■ AQUATIC MAMMALS

Highest frequency



By Cmglee - Own work, CC BY-SA 3.0,
<https://commons.wikimedia.org/w/index.php?curid=35890958>

Noise/sound/vibration...

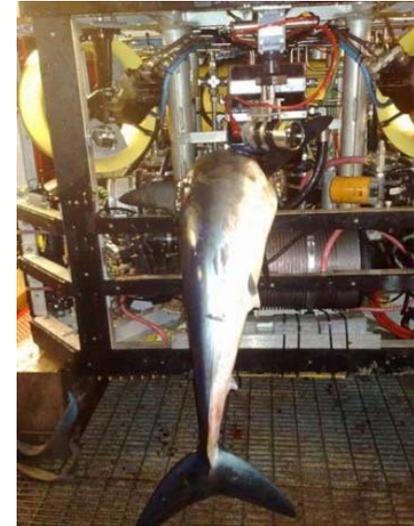
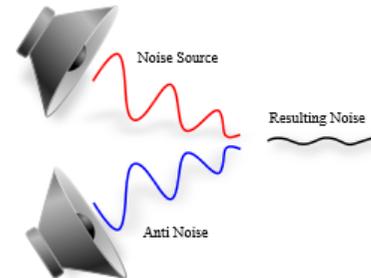
- Sound travels faster and further in water than it does in air
- Some creatures are sensitive to noise in particular frequency ranges
- Many sea creatures use sonar and can potentially be disrupted by certain types of noise
- Sound generation from offshore mining would be similar to dredging, shipping, fishing, oil and gas industry activities etc.
- Sound levels can concentrate when surfaces and inversion layers are present (water surface, seabed, current shifts, temperature inversion layers, cloud layers)
- In shallow waters there is a bigger likelihood of noise concentration
- Ground vibration – unavoidable if cutting, but lower than conventional mining...



310 earthquakes in the past year
(M1.5 or greater)

Mitigation if necessary...

- Minimise noise and vibration generation where possible
- Minimise sound pressure level generated
- Use active noise control/reduction
- Avoid sensitive noise and vibration frequencies
- Use bubble or water jet curtains
- Put a shroud over the machine to muffle the noise if topography allows
- Use acoustic harassment/deterrent devices or sonic barriers (as used in marine aquaculture) to deter pests



Light...

- Sunlight does not penetrate deeper waters
- In deeper water some animals use bioluminescence...



To confuse predators

life



Or to attract and see prey

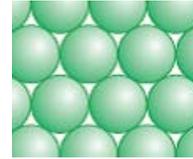
death

- Some critters will be attracted and some will shy away
- Light does not travel far in water

Comparative areal direct habitat loss...

Land = brown
Sea = blue

Even with HCP

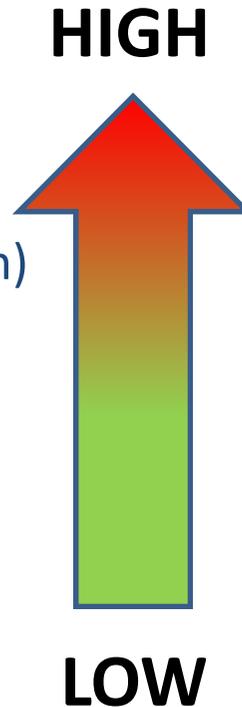


= 60% of



Areal habitat loss (per tonne mined)

- Polymetallic nodules (d=8cm)
- Polymetallic crusts (t=8cm)
- Typical Lateritic deposit
- SMS deposits
- Typical VMS deposits
- Underground mines



Areal habitat loss (per tonne of product)

- Polymetallic nodules
- Polymetallic crusts
- Typical Lateritic deposit
- Typical VMS deposits
- SMS deposits
- Underground mines

Of course, habitat loss can be temporary if the area is rehabilitated or regenerated

Comparative environmental risk...



before

after

- Many seamounts have been bottom-trawled.
- One trawler unit can scour 10km^2 per **day**
- Leaving approximately 4 million tonnes of unpopulated and exposed crust.
- Sufficient for approximately **2 years** of mining!

Prominent Hill...



Bingham Canyon...



Intag (planned mine)...



Comparative impact on ecosystem...

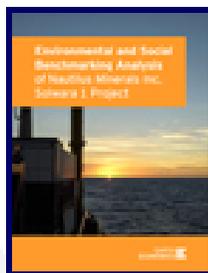
► **Table 4.**
Level of Ecosystem Service
Impact by Mine

| Key | |
|-----|--------------------|
| | Low impact |
| | Moderate impact |
| | Significant impact |
| | High impact |

| Ecosystem Service | Level of Impact (0 = lowest, 3 = highest) | | | |
|-----------------------------------|---|----------------|----------------|-------|
| | Solwara 1 | Prominent Hill | Bingham Canyon | Intag |
| Provisioning Services | | | | |
| Food | 0 | 1 | 3 | 3 |
| Medicinal Resources | 0 | 1 | 1 | 3 |
| Ornamental Resources | 0 | 0 | 0 | 1 |
| Energy & Raw Materials | 3 | 3 | 3 | 3 |
| Water Supply | 0 | 1 | 3 | 3 |
| Regulating Services | | | | |
| Biological Control | 1 | 3 | 2 | 2 |
| Climate Stability | 1 | 1 | 2 | 3 |
| Air Quality | 1 | 0 | 1 | 1 |
| Moderation of Extreme Events | 0 | 1 | 3 | 3 |
| Pollination | 0 | 1 | 1 | 3 |
| Soil Formation | 0 | 3 | 3 | 3 |
| Soil Retention | 0 | 3 | 3 | 3 |
| Waste Treatment | 1 | 2 | 3 | 3 |
| Water Regulation | 0 | 1 | 3 | 3 |
| Supporting Services | | | | |
| Habitat & Nursery | 2 | 2 | 3 | 3 |
| Nutrient Cycling | 1 | 2 | 3 | 2 |
| Genetic Resources | 1 | 3 | 3 | 3 |
| Cultural Services | | | | |
| Natural Beauty | 1 | 1 | 3 | 2 |
| Cultural and Artistic Information | 0 | 1 | 2 | 3 |
| Recreation and Tourism | 0 | 0 | 3 | 3 |
| Science and Education | 1 | 3 | 1 | 2 |
| Spiritual and Historic | 0 | 3 | 1 | 3 |

Carbon footprint...

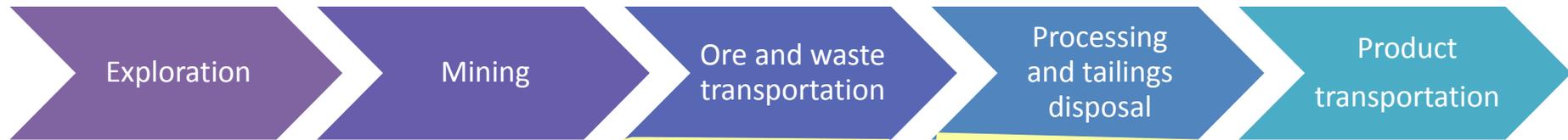
| Mine | Annual Copper Production (metric tons per year) | Annual CO ₂ Emissions (metric tons per year) | Social Cost of CO ₂ Emissions (\$ per ton) | Annual Value of CO ₂ Impacts (\$ per year) | Relative Impact of CO ₂ Emissions per Ton of Copper Produced |
|----------------------|---|---|---|---|---|
| Solwara 1 (proposed) | 77,760 | 346,051* | \$57.30 | \$19,828,722 | 1.0 |
| Prominent Hill | 73,362 | 396,513 | \$57.30 | \$22,720,195 | 1.2 |
| Bingham Canyon | 194,000 | 1,490,000 | \$57.30 | \$85,377,000 | 1.7 |
| Intag (proposed) | 484,437 | Unknown | \$57.30 | Unknown | Unknown |



Environmental and Social Benchmarking Analysis of Nautilus Minerals Inc. Solwara 1 Project



Waste and tailings disposal...



Waste utilisation



Samarco tailings dam failure

In metalliferous mining, the environmental risks can be much greater in the processing part of the value chain

SUBMARINE TAILINGS DISPOSAL IN NORWAY'S FJORDS

Is it the best option?

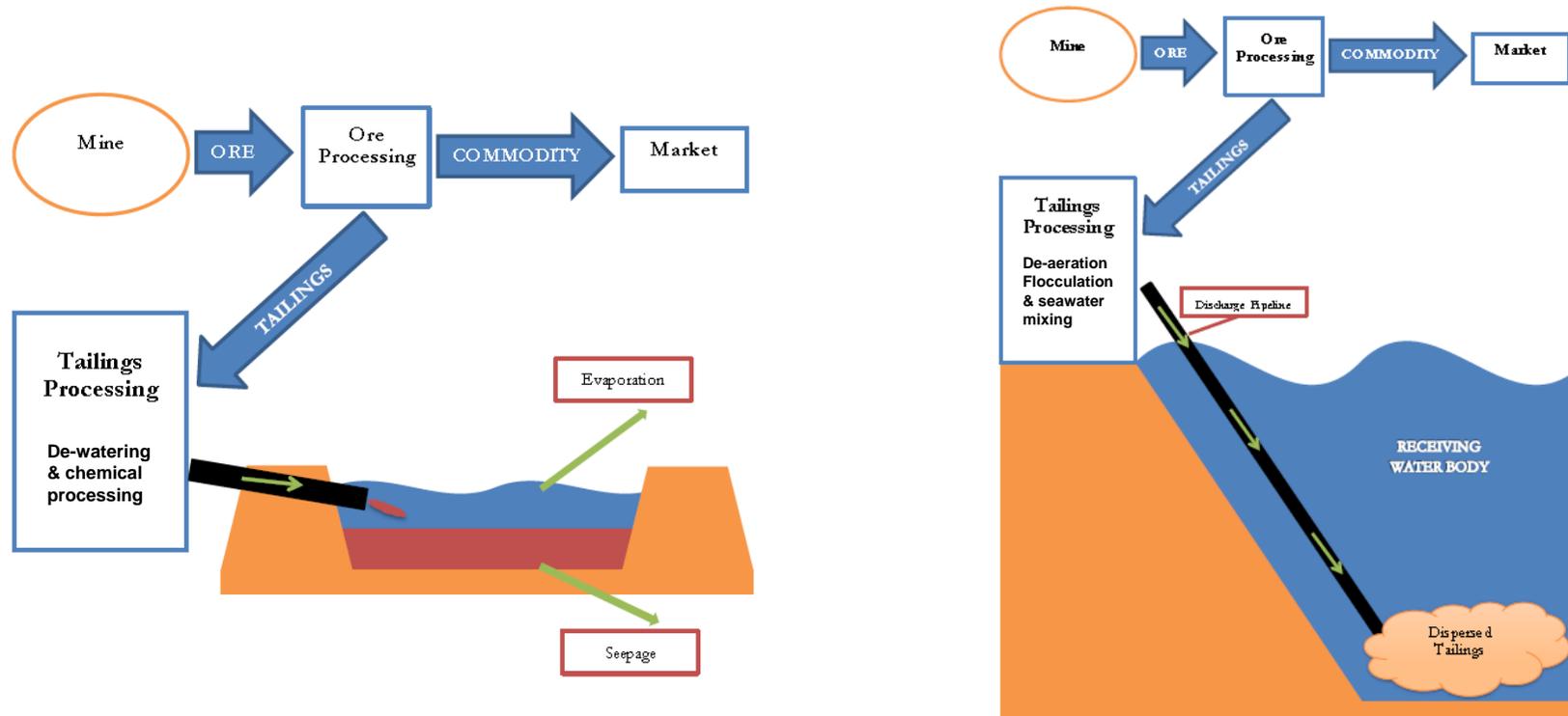
Nathan Cornwall

Supervisor

Peter Arnfalk

Thesis for the fulfillment of the
Master of Science in Environmental
Management

Optional disposal methods...

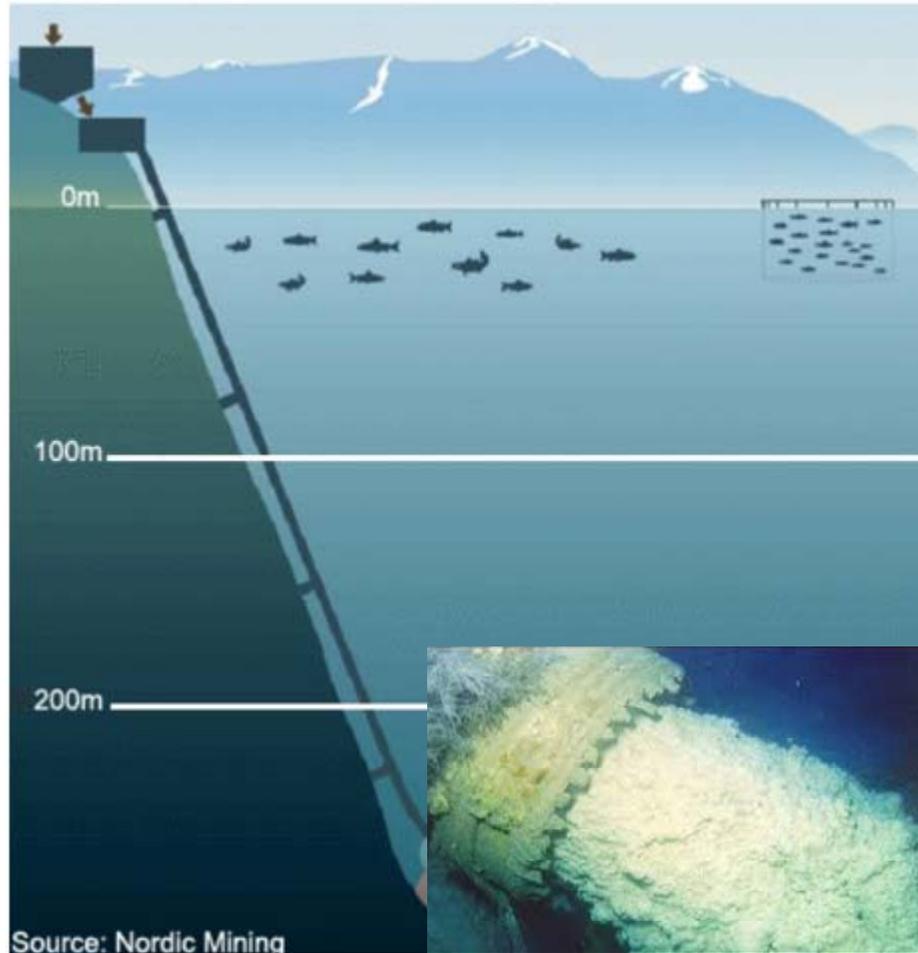


Multi-criteria analysis based on 33 weighted potential impact areas
(high score = high risk)

| Perspective | Land Disposal | Seafloor Disposal |
|------------------------|---------------|-------------------|
| From a mining company | 580 | 287 |
| From regulatory bodies | 370 | 243 |

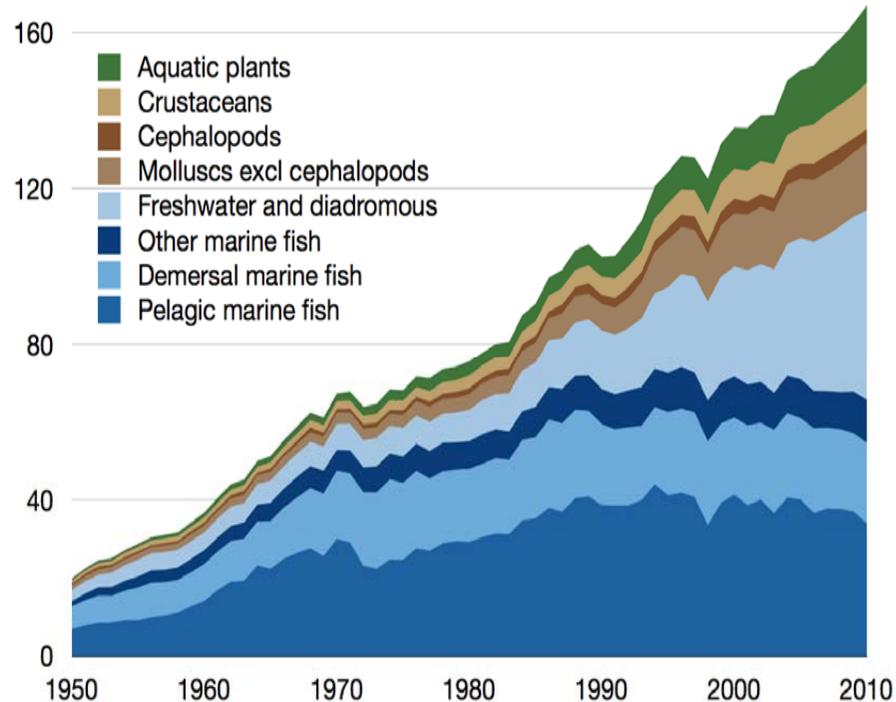
Tailings Disposal...

Deep fjord disposal of mine tailings in Norway



Coordination with other offshore industries...

- Over **150 million tonnes of seafood** consumed per annum...



- And over **2000 whales** taken per annum that we know of...



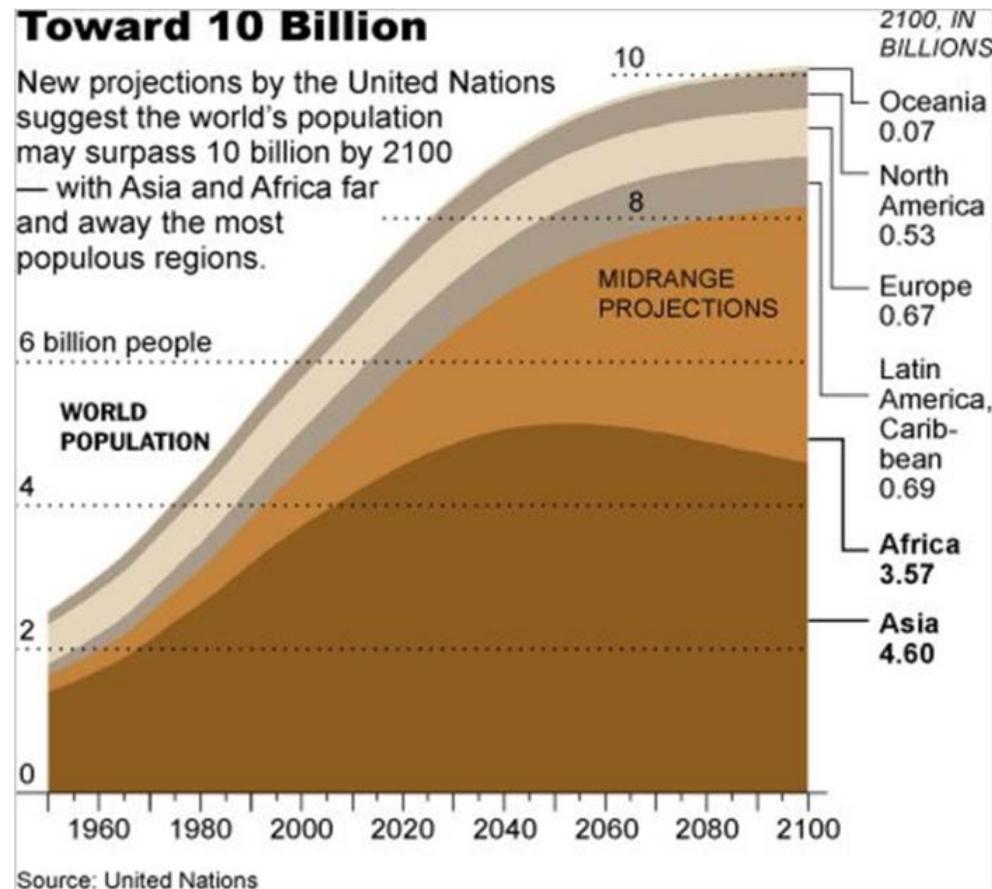
- 1,394 million tonnes of oil** "mined" offshore per annum and lots of exploration drilling...



A question to consider...

- Which of the following would be likely to have the most direct impact on life in the oceans?...
 - a) Extracting 150Mt per annum of seafood
 - b) Extracting 150Mt per annum of crude oil offshore
 - c) Extracting 150Mt per annum of rock
- You could argue that we need to eat the seafood to survive.
- But if you want to use a trawler, you need fuel oil to operate it and metals to build it.
- Clearly there needs to be coordination between industries.

Acceleration of life or human plague?...



- As economies develop there is an increased mineral usage per capita
- The ore grade on land is also diminishing and stripping ratios are increasing

What I would like to see...

All human activity alters the environment. Based on the assumption that we all want a healthier planet, the real question is...

“If we cannot source all the minerals we need through recycling or substitution, and we cannot do without them, which source has the least environmental impact on the planet?”

I would like to see...

more

- Comparative environmental footprint studies (e.g. offshore versus onshore mining)
- Comparative species density (e.g. abyssal seabed plain versus desert, versus rainforest)
- Scalable prototype testing with environmental monitoring

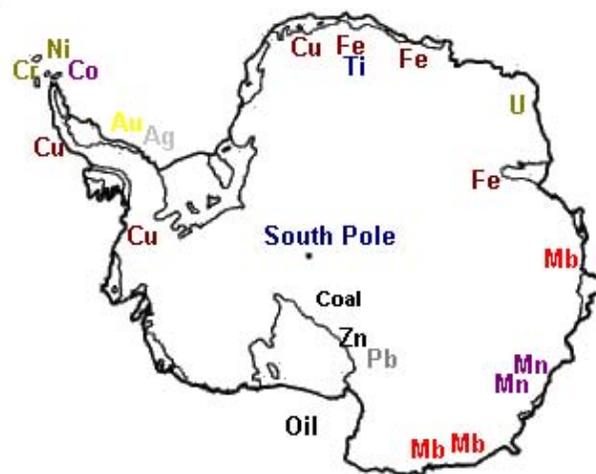
less

- Unsubstantiated scaremongering

Reality...

- To decide to limit or ban mining offshore is potentially bad for the planet
- We would have to increase mining on the land masses leading to a worse comparative environmental effect on the planet
- Given decreasing ore grades and increased stripping ratios, where might that mining take place?

Mining in Antarctica



Mineral map of Antarctica showing known significant deposits of minerals

Key

| | |
|----|--------------|
| Ag | - Silver |
| Au | - Gold |
| Co | - Cobalt |
| Cu | - Copper |
| Cr | - Chromium |
| Fe | - Iron |
| Mb | - Molybdenum |
| Mn | - Manganese |
| Ni | - Nickel |
| Pb | - Lead |
| Ti | - Titanium |
| U | - Uranium |
| Zn | - Zinc |

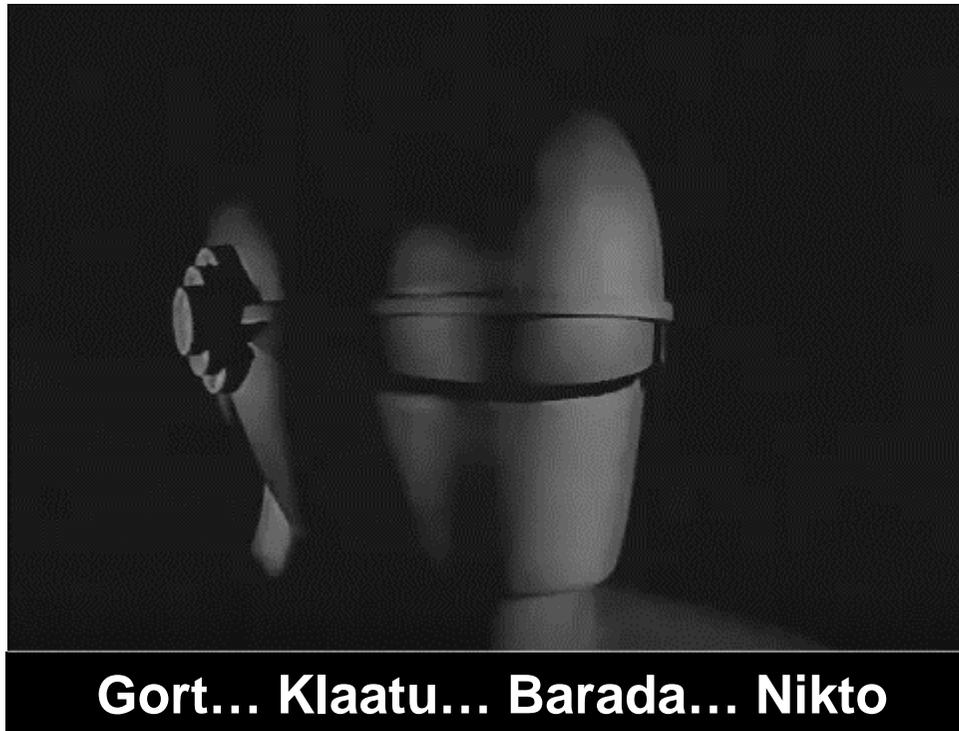
http://www.coolantarctica.com/Antarctica%20fact%20file/science/threats_mining_oil.php

Conclusions...

- We are already mining in the oceans and have been since ancient Greece.
- You can find life forms all over the planet. Everything we do has an impact on life.
- Offshore mining, if done properly, can pose less environmental risk than land mining.
- Offshore mining can pose less environmental risk than other offshore industries.
- The key environmental risks in metalliferous mining are often in the processing stage as opposed to the mining stage.
- If we are over-cautious and favour inland over offshore mining, it could have an adverse net environmental effect on the planet.
- A bad decision in this respect will have ramifications...

Reminder...

What might happen if we make a bad decision and continue to source minerals on land.....



This is potentially a **LIFE** and **DEATH** decision!