Namibia’s “dead zone”
- ecosystem functioning in an extreme environment

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Swakopmund
Namibia
With acknowledgement to colleagues:

The Benguela Upwelling System
Boundary upwelling system
spanning South Africa, Namibia and Angola
What is so special about the seabottom off Namibia?

Northern Benguela Upwelling system

Very productive

Diatomaceous mud belt along the central coast
Namibian surface sediments are high in organic carbon

Diatom-rich mud, organic C: > 12 % dry weight, up to 14 m thick
Pb-210 accumulation rates: 50 - 1000 g/m²/a
Porosity > 90%

Inthorn, 2005
Bottom dissolved oxygen very low: source upwelling water and sediment demand

Integrated 35S-sulfate reduction rates

Brühert et al. (2006)

From Anja van der Plas
NatMIRC OceanBase
During earliest fisheries research cruises 1925-27, this muddy seabottom was noted for hydrogen sulphide and the absence of fish, hence named the “Azoic Zone”.

Marchand (1926) mapped this “azoic” sulphidic seabed within their survey area.
<table>
<thead>
<tr>
<th>Consecutive No.</th>
<th>Station</th>
<th>Description Sort.</th>
<th>Apparatus Tool.</th>
<th>Depth</th>
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27th November, 1925.

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Trawl stations 1925-1927
Fish mortalities along Walvis Bay coast recorded from early 20th century

“A strong odour of sulphur was distinctly noticeable in the atmosphere during the night preceding the first wash-up on the beach, while the sea itself assumed a particularly greenish tinge during the daytime.”

“I have always eaten the fish washed up on the beach....These fish have never made me or my family ill...”
Sea eruptions off South-West Africa

Swakop. S.W.A. Thurs.

The stench of sulphurous sea eruptions pervades the air day and night. Buildings which were white yesterday, are discoloured and black today.

Dead fish are being washed up along the beaches for over 100 miles to the north from Swakopmund………

The sea appears to be boiling with bubbles rising to the surface, but the temperature is only 60 - 70°F.
Outgassing of methane occurs on the inner shelf and is commonly observed.

Methane bubbles

Mud surface collapse

Acoustic image: Stein Kaartvedt

e.g. March 2008
RV G.O.Sars
Sea gas attacks Town

Swakopmund, the small coastal town in South West Africa, is undergoing a gas attack set up by continuous submarine disturbances. Heavy sulphurous fumes... are penetrating as far as 40 miles inland.

......thousands of fish strewn on beach, sharks come into surf gasping on evening tide.

A geologist, discounting volcanic action, says sulphuretted hydrogen......accumulates until it raises islands of mud, which eventually burst.
1900  Mud Island off Walvis Bay
How do these extreme benthic conditions fit into an ecosystem supporting important fishery industries?

- Biological checks, adapted organisms, and key members of the system living at the limits of their oxygen tolerances.
Benthic pelagic coupling

Fish

Benthos
Inner shelf sediment supports mats of giant sulphide-oxidizing bacteria *Beggiatoa* and *Thiomargarita* species.
How do sulphide-oxidising bacteria function?

When available Nitrate $\text{NO}_3^2-$ (or use Oxygen directly)

Fuel: Hydrogen sulphide

Energy

Nitrate store

Sulphur microgranules (white colour)

Thiomargarita namibiensis

Ammonium $\text{NH}_4^+$

S

Water

sediment

Beggiatoa
Large sulphur bacteria oxidize H$_2$S at sediment surface

- stop 55-100% of H$_2$S passing from the sediment to the water column?

(from Levin et al 2003 - California seeps)

Sediment from 115m water depth, Namibia April 2008 Overlying water 0.2ml/L DO
Abundant large sulphide-oxidizing bacteria

*Thiomargarita namibiensis*: in most sediment sulphide-rich areas

*Beggiatoa* spp.: common

*Thioplaca* sp. - scanty in peripheral sulphidic areas

Distribution and abundance varies temporally

~ 3 cm
**Thiomargarita namibiensis**

Thick layers on sediment surface

Namibia’s “chain of pearls”

New morphotypes

chain stained with DAPI (blue) and hybridized

Courtesy Heide Schulz-Vogt
Beggiatoa spp

Filamentous thick mats on the surface bind diatom ooze

Fluid mud with displaced mat

*Nassarius* on mat
158m hake over sulphidic mud covered by large sulphide-oxidizing bacteira
Fauna in surface of sulphidic anoxic mud:

- with bacteria:
- scanty: low diversity, low biomass
- small-bodied, usually red
- polychaetes, molluscs, crustaceans
- nematodes and foraminifera
150-250m less hydrogen sulphide
250 - 350m: animals larger, more abundant
Important component of the benthos:
    Gobies
    *Sufflogobius bibarbatus*

Abundantly distributed over shelf

- major constituent in the diet of hake, seals, many seabirds, often holding trophic chain together

- remarkable ability to withstand both hydrogen sulphide and anoxia

Utne Palm et al 2010
Perform diurnal migration from the mud bottom (DO 0 - 0.2ml/L, sulphide) to oxygen levels of 0.2 - 0.4 ml/L (night).

Gobies use the mud as a refuge from predators and feed on benthos.

Acoustic image Stein Kaartvedt
Lay eggs attached to the seabottom (To remove seabottom would destroy some habitat, their breeding place and food for a lot of our fish stocks).
10-day composite, high resolution acoustics
(10 days day and night)
- inner shelf south of Walvis Bay

March–April 2008 G.O. Sars

Image: Stein Kaartvedt
Hake in bottom water
DO 0.3 - 0.4 ml/L, no sulphide:
- the role of sulphide-oxidizing bacterial mats

150m depth

Video
Rainer Bahlo, IOW
**Distribution of the bearded goby**

- Gobies a major food source for Namibian commercial species hake, horse mackerel as well as seals, penguins, sea birds.

- Gobies are dependent on the anoxic mud to feed, hide and reproduce.

- Gobies not commercially harvested.

- Removal /disturbance of sediments would mean removal of spawning and feeding areas for gobies.
Pressure to bulk mine the seabed off Namibia for phosphorites: bulk removal of the surface sediments to thickness of about 3 metres.

- EPL granted for industrial minerals
- Expired EPL
- Pending EPL (as on 2 April 2012)
- EPLs active
- EPL for diamonds and precious stones (no industrial minerals)
- Mining licenses granted (diamonds or industrial minerals)

EPL localities from Ministry of Mines and Energy website
No active mining of any of the blocks has yet been allowed to begin

- Commercial fisheries and potential mining activities directly overlap.

Following the **PRECAUTIONARY PRINCIPLE**

the Government called a **MORATORIUM**

- First some sound scientific research before any decisions regarding the future of marine phosphate mining
The low oxygen environment poses special questions

- ? edge-zone communities: edge zone must be defined for both benthos and fish
- tolerances and critical levels of oxygen (experimental)
- will upheaval of anoxic sediment overbalance thresholds and tipping points?
- Recovery rates, especially of benthic organisms? Functional recovery?

- For ecosystem functioning: critical areas of spawning, recruitment, refuge, endemism, edge habitat utilization......
- For ecological functioning long-term and cumulative effects: such as sediment to trophic support, carbon burial and sequestration, remineralization and/or sulfide detoxification; linkages between biotic components.
Percentage of low oxygen water <0.5ml/L on the shelf off Walvis Bay 1999- Feb 2012