

An underwater photograph showing a vibrant coral reef in the foreground with various types of coral in shades of orange, brown, and white. In the background, two divers are visible, one in the center and another to the right, both equipped with scuba tanks and masks. The water is clear and blue, with sunlight filtering through from above.

MARINE ALGAE AND CLIMATE CHANGE: ADAPTATION AND MITIGATION

PHANG SIEW-MOI

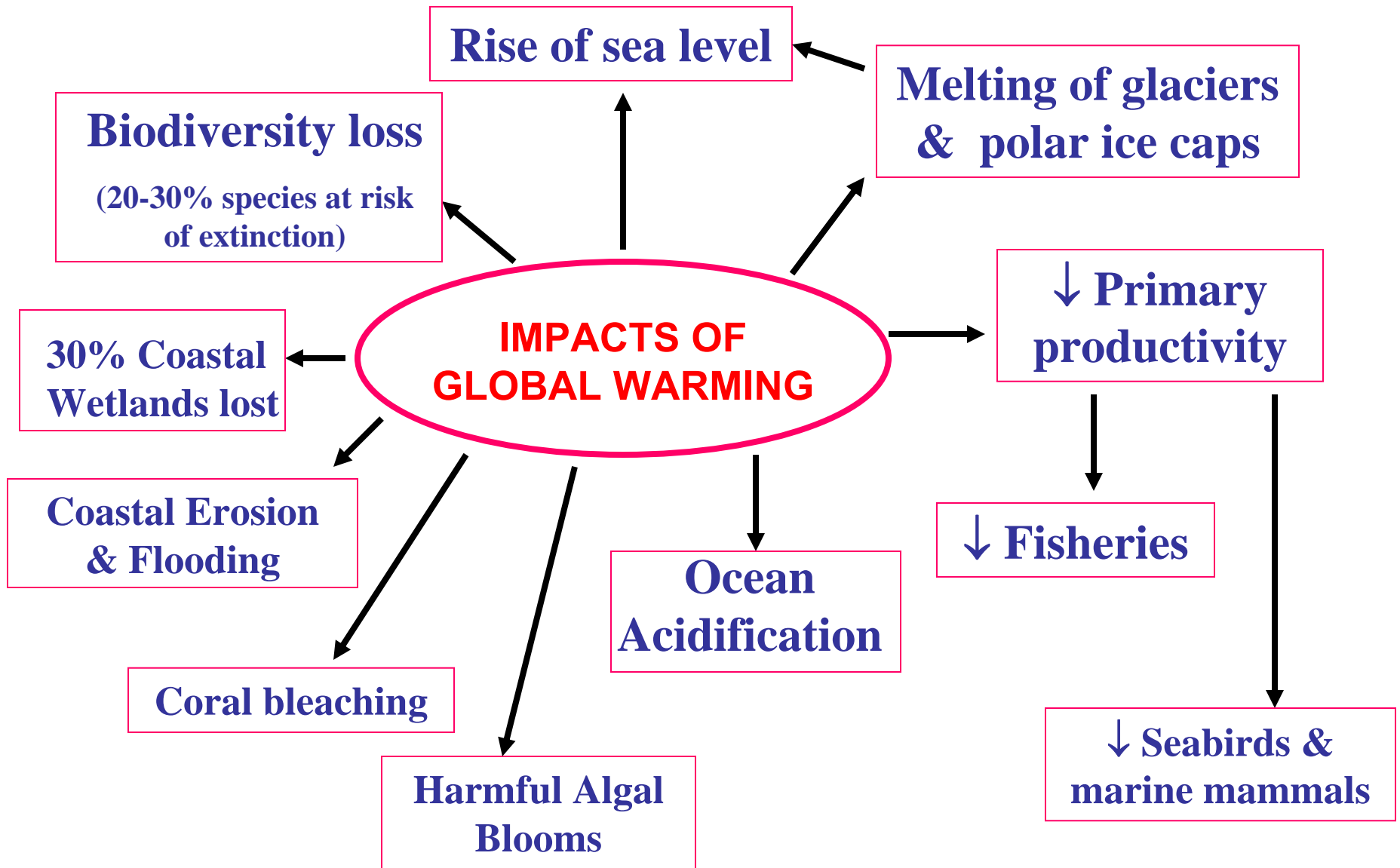
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Climate Change & the Marine Ecosystems (Oceans, Coasts & Islands)

Scenario:

- Between 2000 to 2030 → global GHG increase by 25-90% with fossil fuel as dominant energy source
- warming of 0.2°C per decade
- Sea level rose by $3.1 \pm 0.7 \text{ mm yr}^{-1}$ [Climate Change 2007: The Physical Science Basis, Solomon et al.(eds.)]
- Warming greatest over land & high Northern latitudes; least over Southern Ocean & parts of North Atlantic Ocean
- Contraction of snow cover, increase in thaw depth over most permafrost areas, decrease in sea ice extent, Arctic sea ice cover may disappear by late 21st century
- Increase of hot extremes, heat waves, heavy precipitation
- Increase in tropical cyclone intensity



ADAPTATION IN MARINE ECOSYSTEMS

Vulnerability to climate change is determined by economic, social and environmental factors

Resilience of the marine ecosystems likely to be exceeded by combination of climate change, associated disturbances (eg. ocean acidification) & other global change drivers (eg. pollution) → species extinction → coral bleaching → decrease in primary productivity; → Arctic & small island communities have increased vulnerability

Adaptation (activities to reduce impacts of climate change) can reduce vulnerability. Adaptive capacity is related to social & economic development but unevenly distributed across societies.

Mitigation

Mitigation (reduction of sources or enhancement of greenhouse gas sinks)

Management of Ecosystem Resources → reduce emissions, climate change impacts & biodiversity loss

Ecosystems may be prioritised on basis of importance to climate system, biodiversity value & ecosystem services provided (Biodiversity-Climate Interactions: adaptation, mitigation & human livelihoods, Royal Society, 2007)

Ecosystem Type	Climate regulation	Biodiversity & ecosystem services values	Mitigation potential	Adaptation potential	Benefits for human well-being	Co-benefits
Peatland/wetland	Carbon store	High	High	High	Medium	High
Tropical forest	Carbon store, water cycling	Very high	High	High	High	Very high
Oceans	Carbon sink, water cycling	High	Low	Low/ Medium	High	Medium
Coral Reefs	Carbon cycle	Very high	High	High	High	High

(Biodiversity-Climate Interactions: adaptation, mitigation & human livelihoods, Royal Society, 2007)

Asian Network for Using Algae as a CO₂ Sink

Insufficient data

•Initiated in 2005 by Prof. Ik Kyo Chung, Coordinator of the project :Greenhouse Gas Emissions Reduction by using Seaweeds”; 16 countries; under the auspices of the Asian-Pacific Phycological Association.

ROLE OF OCEANS IN CARBON DIOXIDE ABSORPTION

1. Physical Absorption of Atmospheric Carbon Dioxide By The Oceans

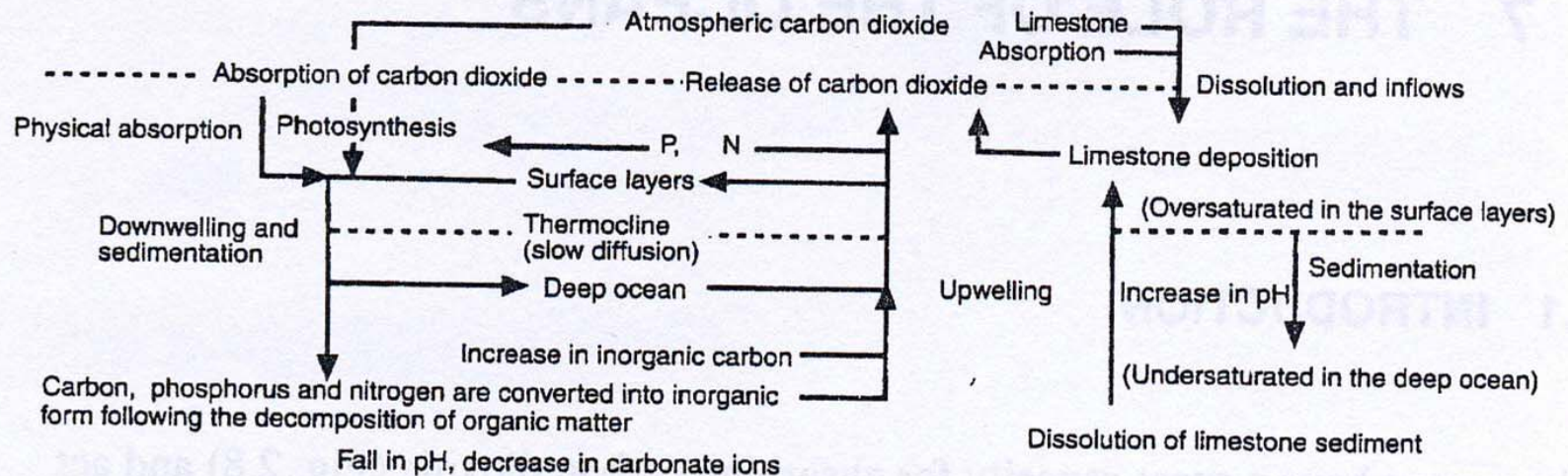
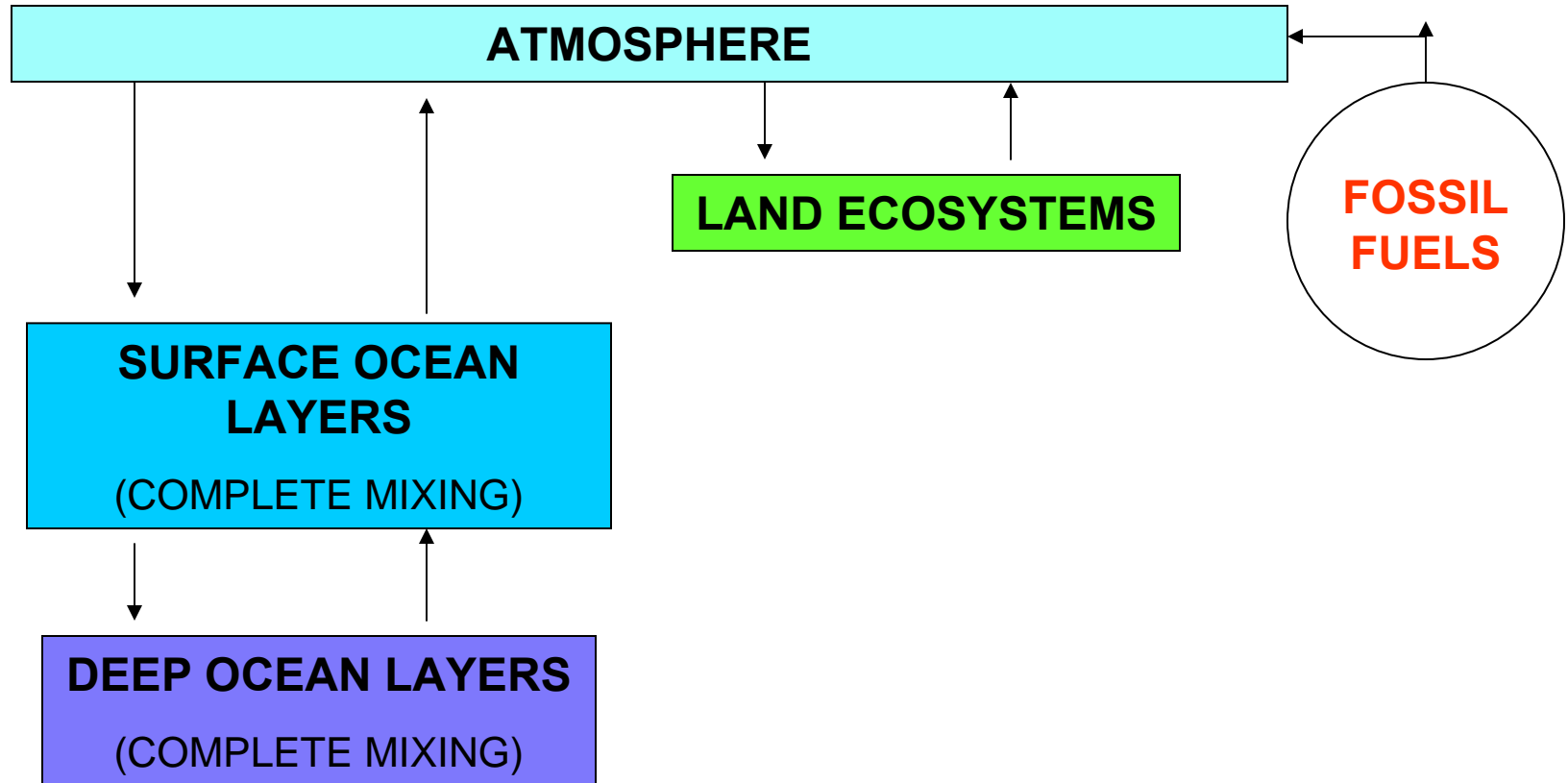


FIGURE 7.1 Circulation of carbon and sea water in the oceans.

[The Carbon Dioxide Problem. Kojima T & Harrison B (1998)]



TWO-BOX MODEL FOR CALCULATING AMOUNT OF CARBON DIOXIDE ABSORBED BY OCEANS

The well-mixed surface layer and well mixed deep ocean are separated by a region of poor mixing (thermocline)

[The Carbon Dioxide Problem. Kojima T & Harrison B (1998)]

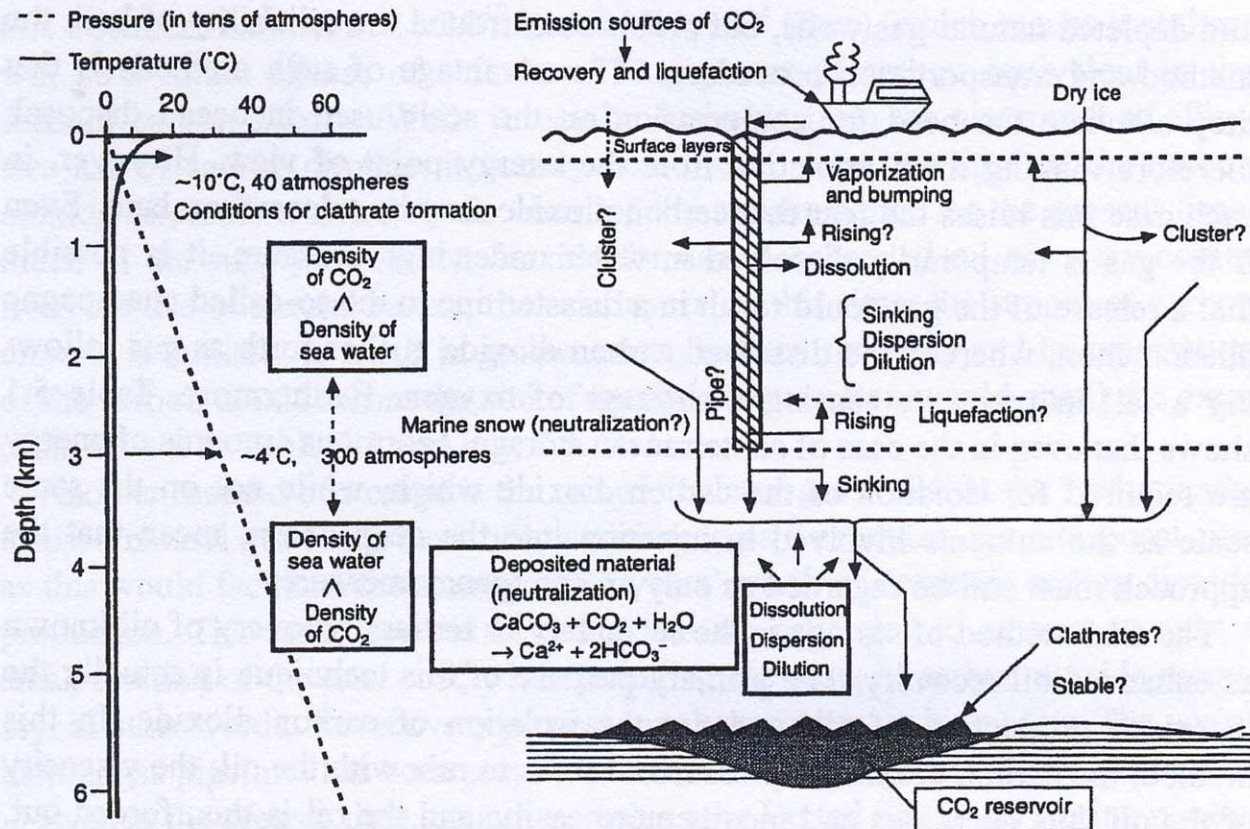


FIGURE 5.11 Ocean properties related to the ocean disposal of carbon dioxide [adapted from Nishio 1992].

[The Carbon Dioxide Problem. Kojima T & Harrison B (1998)]

Option:

1. Ocean Disposal → Much research still needed

→ Short-term measure

2. Marine Species

- Phytoplankton, seaweeds, seagrasses
- Corals
- Calcified species like coccolithophorids
- Shellfish : abalone, oyster

→ Nutrient limitations (N, P) → Iron Fertilisation?

→ Artificial Upwelling?

Options:

1. Seaweed Farms
2. Microalgae Farms
3. Coral Farms
4. Integrated Farming of Shellfish , Corals & Seaweeds

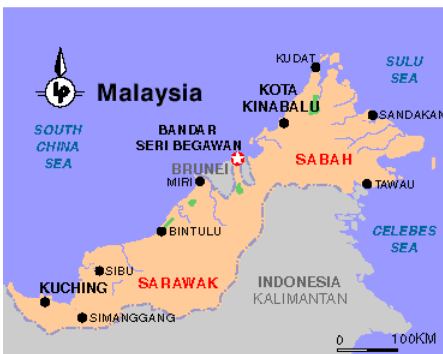
ADAPTATION & MITIGATION OF CLIMATE CHANGE IN MALAYSIA

- Global mean surface temperature projected to increase 1.4 to 5.8°C
- Global mean sea-level rise 9 to 88cm by year 2100
- Malaysia: a sea level rise of 100cm will result in 7000km² land loss (2.1%), with >0.3% of the population exposed.
- **Malaysia (2004):**

→ carbon load : 1,280,164 tonnes

→ nitrogen oxides load: 305,401 tonnes

- Source: traffic, industries and power plants



Malaysia Ratified the UNFCCC on
13 July 1994

MALAYSIA'S CLIMATE RELATED POLICIES

1. Legislations

- **Environmental Quality Act**
- **Land Conservation Act**
- **Forestry Act**
- **Protection of Wildlife Act**
- **National Parks Act**
- **Marine Parks Malaysia Order**
- **Sarawak Biodiversity Centre Ordinance**

3. International Agreements

- **UNCLOS • CITES • CBD**
- **MARPOL • RAMSAR**
- **KYOTO PROTOCOL**

2. National Policies

- **National Biodiversity Policy**
- **National Agricultural Policy**
- **National Forestry Policy**
- **National Physical Plan**
- **National Ecotourism Plan**
- **National Environment Policy**
- **National Transport Policy**

Projects (Marine related) by the Malaysian National Climate Committee:

1. Effects of oceans on atmosphere
2. Ozone monitoring and research
3. Carbon fluxes in mangrove ecosystem
4. Modelling and simulation of salt water intrusion in coastal aquifers
5. Climate variability and long-term predictions of monsoons
6. Human-physical interactions on coastal systems: with special reference to land reclamation
7. Impact of sea level rise on coastal systems/zones in Malaysia
8. Adaptation of a coupled ocean-atmosphere general circulation model
9. Develop a National Climate Policy and Strategy
10. Implement public awareness programmes

ADAPTATION

•Coastal Protection using Bioengineering

This project involves the establishment of mangroves and other coastal plant species using a combination of technical and bio-technical solutions to dissipate wave energies, site stabilisation and planting of pre-grown plant seedlings. It incorporates the installation of the concrete L-Blocks as a hard engineering option, and primary wave breaker. Behind this row of concrete blocks are three rows of artificial system for mangroves and geo-materials acting as secondary wave breakers and sediment traps. Seedlings of mangrove and other coastal plant species are planted behind the hard and soft wave breakers, using bio-technical techniques. Seaweeds and sea grass are planted for ecological and economic enhancement of the habitats, as well as cockle spats for local consumption. Ecological engineering is the use of living or dead plant materials in combination with inert materials like cement or steel, for ground stability.

•Mangrove replanting

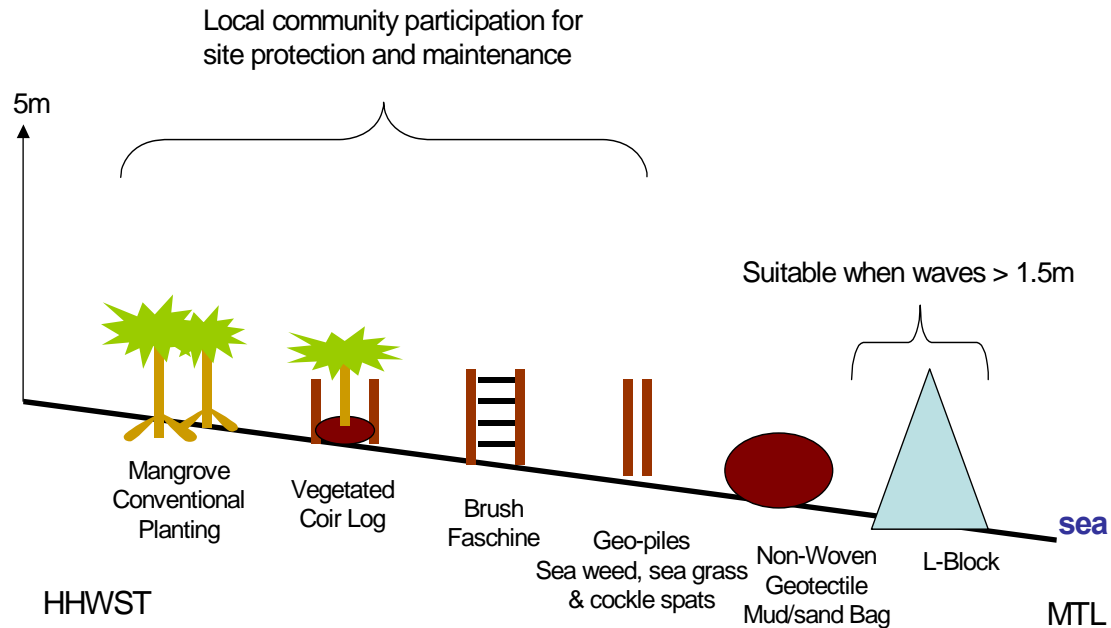
•Impact of sea level rise: Integrated Coastal Zone Management, Land Reclamation

•Research on Response of Species to Climate Change

•Undertake a coastal vulnerability index study (CVI) to serve as basis for recommending proactive adaptive measures to mitigate impacts of sea level rise

Project design

Each project site will be protected by outer civil structures (1 row of interlocking concrete or H-Blocks, and 3 rows (each row with 100 units) of Artificial Roots System for Mangroves, ARMS) and inner geo-structures (faschines, coir logs) as the first and second line of defence against strong waves. Mangroves, other coastal vegetation, seaweed, sea grasses and cockle spats will be established between these wave breakers and the coastline. A mangrove seedling wetlands nursery will be set up to provide healthy, pre-grown seedlings on coir logs or other suitable bio-substrates to ensure good plant establishment on site.



MITIGATION: CONTROL OF GREENHOUSE GASES

1. Reduce emissions

- i) Increase use of renewable energy in power generation (hydro power, gas)
- ii) Biofuels
- iii) Implement energy efficiency programmes in industries, buildings, motor vehicles & transport systems.
- iv) Promote sustainable management of forests to preserve biodiversity and sinks for GHG
- v) Capture biogas from landfills and oxidation ponds for energy

2. Increase sinks of carbon

Technologies:

- i) Conversion of CO₂ in flue gases by photosynthesis to food : culture algae (*Spirulina*)
- ii) Ocean nourishment with nitrogen to increase primary productivity . Can sequester up to 8 Mt CO₂ per year
- iii) Patch fertilisation of oceans eg. Addition of micronutrient iron.
- iv) Carbon sequestration through calcium carbonate incorporation eg. Coccolithophorids; Corals; shellfish
- v) Culture seaweeds



Plants as carbon sinks

Tropical forests: 212 Gt.C

Tropical biosphere sink : -1.6 Gt.C.yr

Malaysia, Pasoh Forest: CO₂ flux from -2.1
to -2.6 gC.m⁻².d⁻¹



Marine Ecosystem ?

Net primary productivity in seaweeds range from:

Laminaria (temperate) 20gC.m⁻².d⁻¹

Sargassum (tropical) 2500 gC.m⁻².d⁻¹

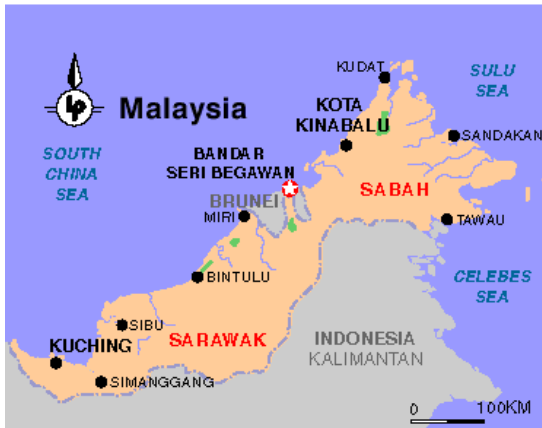


SEAWEED INDUSTRY IN MALAYSIA

Three companies culturing red seaweeds, mainly *Kappaphycus* and *Eucheuma*, and two factories producing semi-refined carrageenan and chips in Sabah.

In 2002 Sabah's aquaculture production comprised of 74.6% seaweed, 22.3% shrimp, 2.2% fish and 0.9% mollusc, which together contributed to 19% of the national production.

In the period from 2000-2003, the seaweed production ranged from 2565 to 4101 metric tonnes bringing a revenue ranging from US\$ 2 to 5 million per annum



Tacara Sdn Bhd.: natural carrageenan production

MASS CULTIVATION OF *KAPPAPHYCUS* IN SABAH

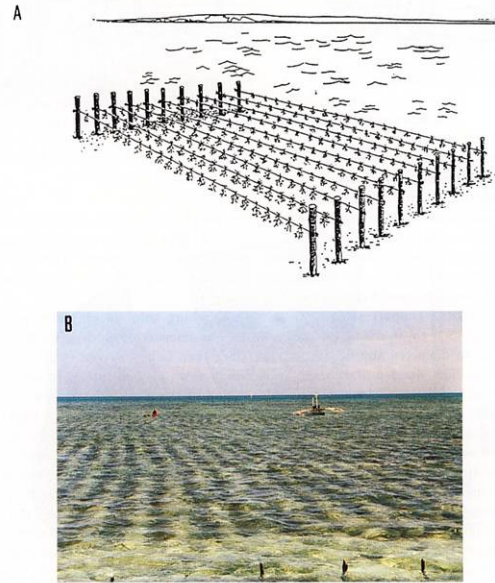


Figure 9. A. Fixed, off-bottom monoline method of farming *Eucheuma* and *Kappaphycus*. B. A typical *Eucheuma* farm in Danajon Reef, Bohol, Philippines. One thousand, 10 m long monolines will make one hectare of farm.



Integrated Shellfish & Seaweed Farms



Seaweed Productivity : 3 to 46 gDW.m⁻².d⁻¹

How can seaweed farming contribute to CO₂ reduction in Malaysia?

Carbon Budget for a Seaweed Farm

1. Total area of seaweed farm
2. Growth Rates, Total biomass Production
3. Carbon store in biomass & in seawater, sediment, atmosphere
4. Carbon absorption/Gas exchange
5. Rate of photosynthesis (Gross & Net)
6. Primary Production (Gross & NPP)
7. Model development (eg. NPP models)
8. Fate of the post-processing seaweed biomass & products
(Ethanol, biogas?) [Life Cycle Analysis]
9. Management options

Species	Productivity (Growth rates)	References
<i>Eucheuma</i> <i>/Kappaphycus</i> spp	0.15 kg/day	Phang 2006
<i>Gracilaria</i> <i>changii</i>	3.3 – 8.4 %/day	Phang et al. 1996
<i>Sargassum</i> <i>binderi</i>	81 dw /m² (maximum standing biomass)	Wong et al. 2004
<i>S. baccularia</i>	65 dw /m² (maximum standing biomass)	Wong et al. 2004

COLLABORATION THROUGH THE ASIAN NETWORK

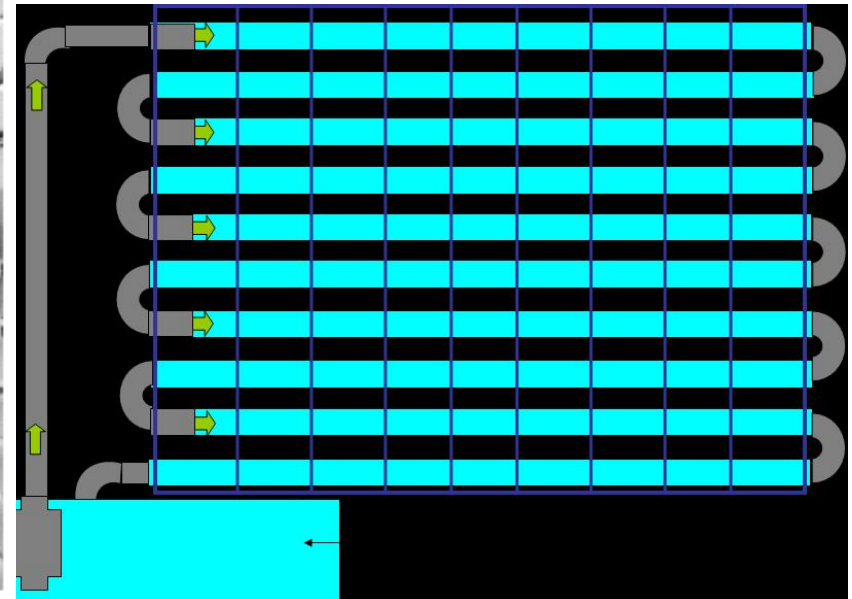
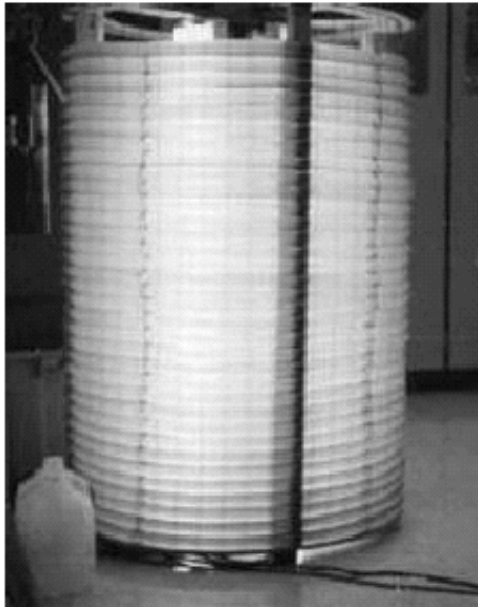
1. Establish database on algal primary productivity in natural freshwater and marine habitats.
2. Correlate productivity and CO₂-sink potential to abiotic factors, especially levels of CO₂, pH, temperature, nutrients, etc.
3. Develop models for : i) freshwater ecosystems as C sinks
ii) oceans as C sinks
4. Investigate and develop appropriate mass cultivation technology for use of microalgae and seaweeds for CO₂ removal.
5. Investigate and optimise ocean fertilisation for enhancing primary productivity.
6. Search for strains tolerant to high CO₂ levels, high temperature strains.
7. Genomics for identification of useful genes.
8. Develop transformation systems for strain development.
9. Assess alternative biofuels from marine resources (ethanol, biodiesel, biogas)

PHOTOBIOREACTORS

Huan, Global Satria Sdn. Bhd.



- PhotoBioReactors or PBR for short allows high efficiency algal culture.
- This platform will allow us to grow Algal DNA vaccines, Algae as specialized Protein Expression systems, Nutraceuticals, and perhaps tap into the Carbon Credit market worth USD60 billion/yr according to *The Economist*.
- PhotoBioReactors on a Mega-scale with a radical design will be required for significant Carbon sequestration. Such designs must be field tested and validated by the United Nations Commission on Climate Change.
- Kyoto Protocol Phase 1 begins 2007, phase 2 in 2008 (€40/mt CO₂/€100/mt CO₂)



Location of Coral Reefs - Reef by Type



Data Sources

<http://reefgis.reefbase.org>



Reef by Type





Research is also underway to use the Giant Tropical Oyster (1kg each) to feed on algae in prawn ponds to sequester carbon dioxide into the shell that is mainly calcium carbonate.

CO2 absorption will help us against Climate Change !

Huan, Global Satria Sdn. Bhd.



Bullet proof buoy



GLOBAL SATRIA S/B

Wave-driven piston powered upwelling

Seaweed culture in nutrient rich-waters

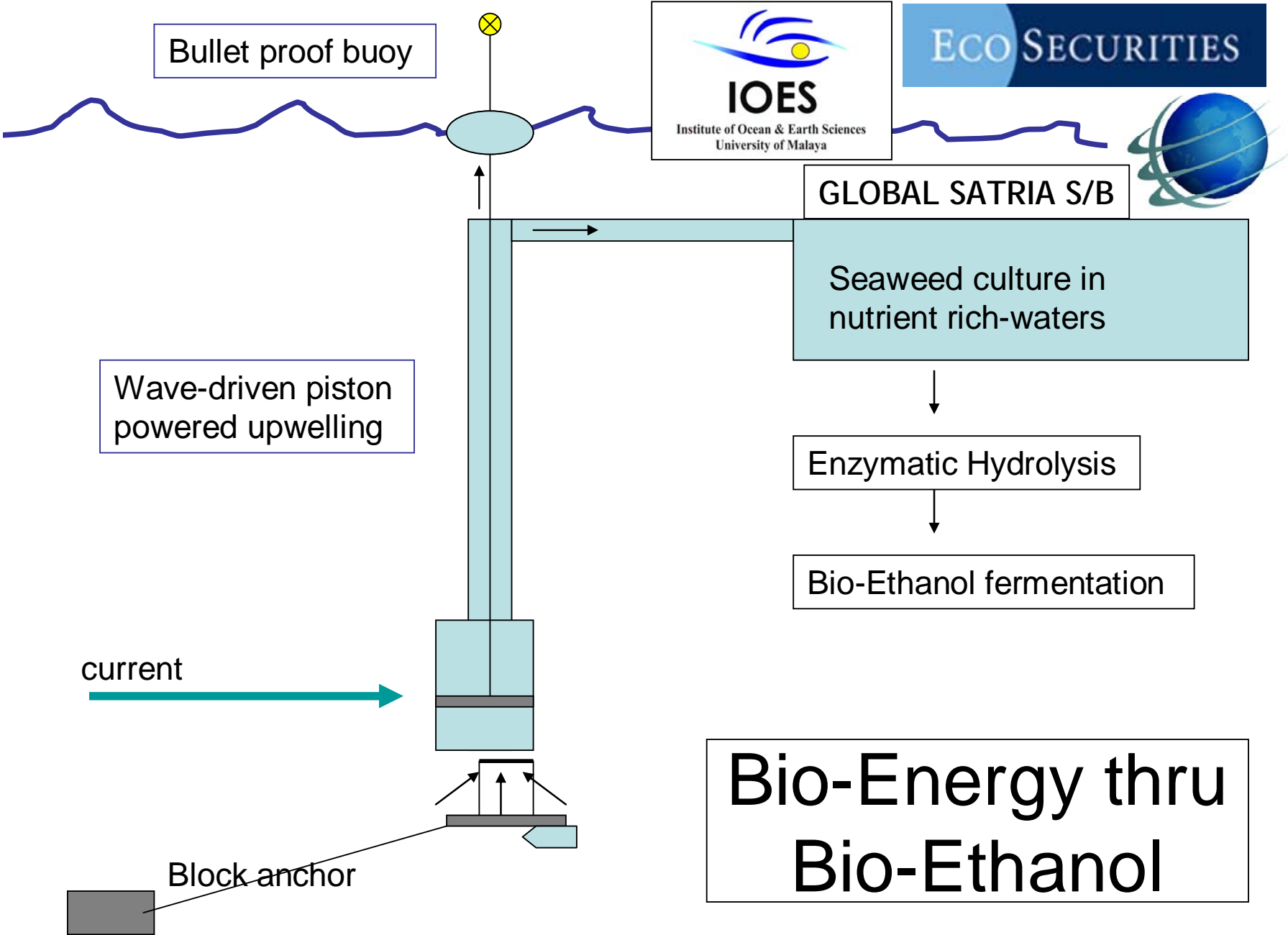
Enzymatic Hydrolysis

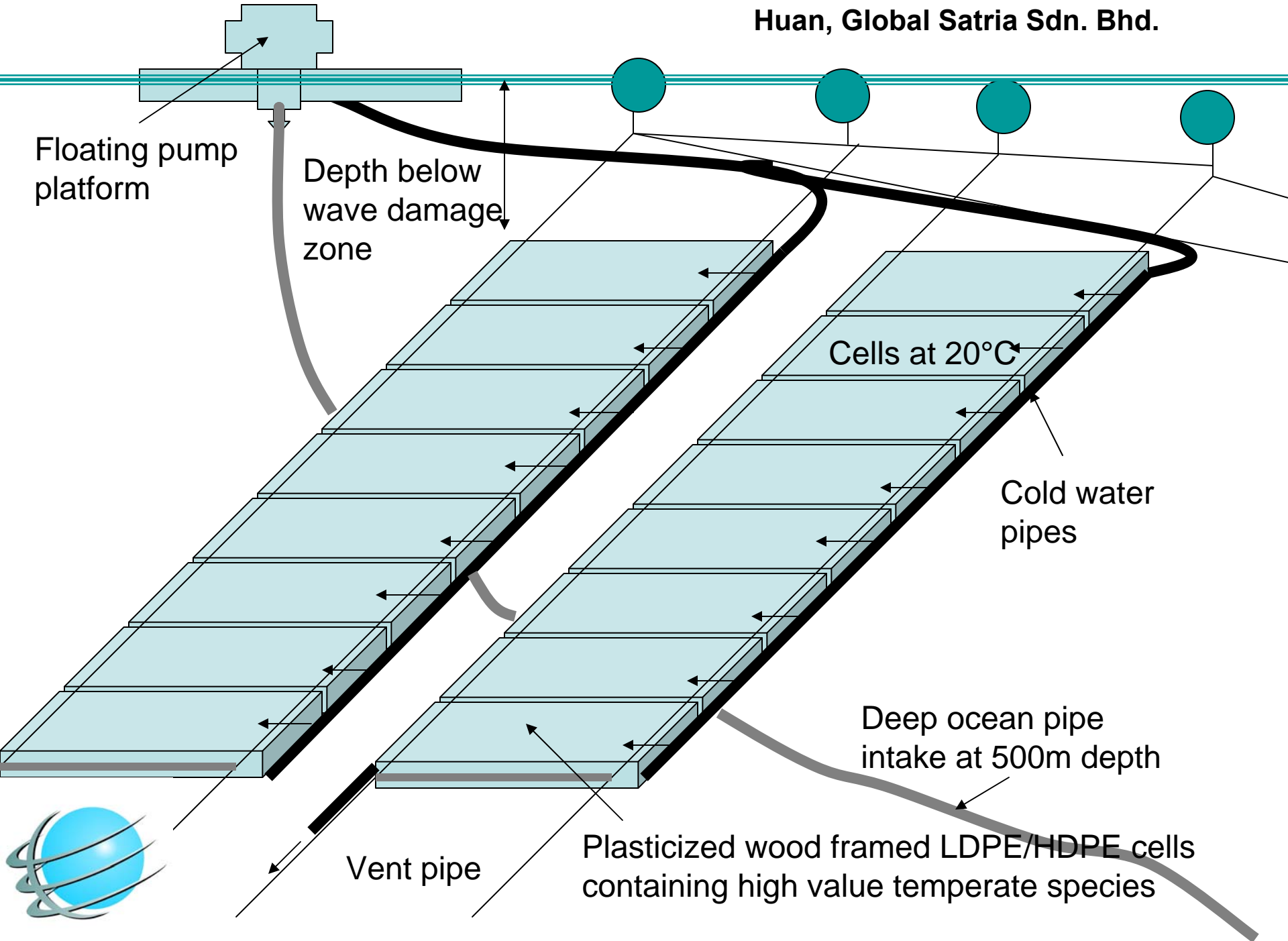
Bio-Ethanol fermentation

current

Block anchor

Bio-Energy thru Bio-Ethanol





IPY EOI No. 96: Response of Polar, Tropical and Temperate Microalgae to Global Warming and Increased UV Radiation



Project Leader: Phang Siew-Moi (University of Malaya); Deputy Project Leader: Chu Wan-Loy (International Medical University, Malaysia) ; Co-Researchers: Rofina Yasmin Othman (University of Malaya), Ng Kim-Yong (Malaysia University of Science & Technology), Ho Chai-Ling (University Putra Malaysia), Christian Wiencke (AWI, Germany), John Beardall (Monash University, Australia), Hideaki Miyashita (Kyoto University, Japan)

RESEARCH QUESTION

How do polar algae respond to global warming and increased UVR compared to tropical & temperate algae?



OBJECTIVE

To compare the response of Polar, Tropical and Temperate microalgae to UVR and temperature stress, with the aim of correlating such physiological traits with their diversity in the various geographical regions.



PROJECT ACTIVITIES

1. Expeditions to the Arctic & Antarctic → collection of polar algae & conduct field studies
2. Investigate the physiological & biochemical response of the algae to temperature & UVR stress – e.g. carbon fixation & nutrient uptake
3. Investigate the molecular basis of stress adaptation in algae – subtractive DNA library, gene probes for stress markers, molecular fingerprints & gene expression
4. Investigate the functions and mechanisms of oxidative stress enzymes based on genomic and proteomic properties.

This project is under the IPY Consortium Project (IPY EOI 429) on Microbiological and Ecological Responses to Global Environmental Changes in Polar Regions (MERGE)

One question is: **How do polar algae respond to global warming and increased UVR compared to tropical & temperate algae?**

→ Results show that if global warming happens, the food web in Antarctica will suffer because of the reduced nutritional (fatty acid and carbohydrate) value of the microalgae.

→ Antarctic and Temperate algae share a similar strategy in response to temperature increase, while Tropical algae are already living near their upper limits.

→ The understanding of the response and adaptation of algae to changing climate at both the cellular and molecular level, can lead to adaptation strategies in climate change as well increasing the vulnerability of species and ecosystems.