UNESCO-IOC Sub-Commission for the Western Pacific
Southeast Asian Global Ocean Observing System
(SEAGOOS)

OCEAN ACIDIFICATION AND ITS IMPACT TO
MARINE ECOSYSTEM (OAIME)

SEAGOOS Pilot Project

By Dr.Somkiat Khokiatwiwong and Dr.Suchana Chavanich
Ocean Acidification

How will changes in ocean chemistry affect marine life?

Carbon dioxide from the atmosphere reacts with water and carbonate ions to form bicarbonate ions:

$$\text{CO}_2 + \text{H}_2\text{O} + \text{CO}_3^{2-} \rightarrow 2 \text{HCO}_3^-$$

Consumption of carbonate ions impedes calcification.
When carbon dioxide (CO2) is absorbed by seawater, chemical reactions occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals.

Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH units. Since the pH scale, like the Richter scale, is logarithmic, this change represents approximately a 30 percent increase in acidity. Future predictions indicate that the oceans will continue to absorb carbon dioxide and become even more acidic. Estimates of future carbon dioxide levels, based on business as usual emission scenarios, indicate that by the end of this century the surface waters of the ocean could be nearly 150 percent more acidic, resulting in a pH that the oceans haven’t experienced for more than 20 million years.

The photos below show what happens to a pteropod’s shell when placed in seawater with pH and carbonate levels projected for the year 2100. The shell slowly dissolves after 45 days. Photo credit: David Liittschwager/National Geographic Stock
Atmospheric CO$_2$ was steady for at least 1,000 years before the industrial revolution.

Adapted By Dr. Christopher L. Sabine from Sarmiento and Gruber 2002 using Trends online data
CO$_2$ and pH time series in the North Pacific Ocean. Adapted from Feely (2008)
Ocean Acidification: Historical Perspective

- For the last 20 Million years the pH of the ocean has remained relatively stable between approximately 8.1 and 8.2

- The uptake of anthropogenic CO$_2$ has lowered ocean pH by 0.1, representing a 30% increase in acidity over the last 200 years.

- The estimated drop in pH by the end of the century is not only larger than seen over the last 20 million years, but is also at least 100 times faster than in the past.

Turley et al., 2006
Ocean Acidification: Fundamental Chemistry

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \\
\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^- \\
\text{H}^+ + \text{HCO}_3^- \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

• More than 99% of the H\(^+\) formed consume \(\text{CO}_3^{2-}\) to form \(\text{HCO}_3^-\) making it more difficult for organisms to form their shells.

CO\(_2\) is an acid gas so the addition of 22 million tons of carbon dioxide to the ocean every day is acidifying the seawater...we call this process “ocean acidification”

By Dr. Christopher L. Sabine
What Effect to Coral Calcification?

- Symbionts (Zooxanthalae)
- Temperature
- Light
- Turbidity
- Nutrients
- Aragonite Saturation
- Alkalinity and pH

**Titration method**

**$pCO_2$ and DIC**

**pH meter**
Ocean Acidification: Fundamental Chemistry

\[ \text{Ca}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CaCO}_3 \]

\[ \Omega > 1 \quad \text{CaCO}_3 \text{ stable} \]

\[ \Omega = 1 \quad \text{equilibrium} \]

\[ \Omega < 1 \quad \text{CaCO}_3 \text{ dissolves} \]
Saturation States in the Pacific

Hoegh-Guldberg et al. 2007: $\Omega_{\text{arag}} = 3.3$

Shamberger et al. 2011
Mean Annual Air-Sea Flux for 2000 [Rev Dec 10] (NCEP II Wind, 3,040K, γ=26)

Aragonite Saturation Levels in 1765

Aragonite Saturation from Orr et al 2005
Coverage for SE Asia
Aichi Biodiversity Targets

- **Strategic Goal A**: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society.
- **Strategic Goal B**: Reduce the direct pressures on biodiversity and promote sustainable use.
- **Strategic Goal C**: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.
- **Strategic Goal D**: Enhance the benefits to all from biodiversity and ecosystem services.
- **Strategic Goal E**: Enhance implementation through participatory planning, knowledge management and capacity building.

**Target 8**
By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

**Target 10**
By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

**Strategic Goal B**: Reduce the direct pressures on biodiversity and promote sustainable use.

- **Target 5**: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.
- **Target 6**: By 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem-based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.
- **Target 7**: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.
- **Target 8**: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
- **Target 9**: By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.
- **Target 10**: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.
Oxygen Minimum Zone (OMZ)
Introduction of a new way to study on the effects of Ocean Acidification on coral reef ecosystems by Xu Dong, Aiqin Han and Weidong J.

Calcification rate of coral (Doney et al., 2008; Fabry et al., 2008; Zhang et al., 2012; Leclercq et al., 2000)

Atmospheric CO2

Seawater CO2

40%

pH 0.1

Ω Arag 16%

Ω Cal 16%

Calcification rate of coral 9%

(Doney et al., 2008; Fabry et al., 2008; Zhang et al., 2012; Leclercq et al., 2000)
Upwelling can bring “acidified water” of which the pH is low to the surface. (Feely et al., 2008)

Upwelling may supply a direct field evidence for the study of OA
Oceanographic surveys

Internal wave on early of this year (2007)

Sampling Site: West Coast of Ko Meing, March 2007 at fix depth 40 m (total depth 50-55 m)
Biological Aspects:

Corals on western side

© Niphon Phongsuwan

Corals on eastern side

© Mélanie Bon

Graph showing height from bottom [cm] of coral framework for different locations:
Influence of pCO₂ on coral larvae and the monitoring of carbonate system in a Thai reef

By Suchana Apple Chavanich, Narainrit Chinfak, Wipada Lalitpattarakit and Voranop Viyakarn

Settlement rates of *Pocillopora damicornis* larvae

<table>
<thead>
<tr>
<th>Percent (%)</th>
<th>Control</th>
<th>7.9</th>
<th>7.6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.9</td>
<td>7.6</td>
<td></td>
</tr>
</tbody>
</table>
Preliminary data:
Effect of pH on the settlement rate of *Acropora millepora* larvae.
Preliminary data:
Effect of pH on the fertilization of *Acropora millepora* larvae
Studies on the ecology of a coral reef in the vicinity of an underwater thermal vent as a window to the future survival of tropical shallow reefs exposed to ocean acidification

Changes in coral genus along the pH gradient

By Zulfigar Yasin\textsuperscript{1, 2}, Nithiyaa Nilamani\textsuperscript{1}, Zulfikar\textsuperscript{1, 3} Norhanis Razalli\textsuperscript{1}, and Tan Shau Hwai\textsuperscript{1}

Increasing distance away from the main vent
Bivalve Aquaculture and ocean acidification in Southeast Asia
By Aileen Tan S. H., Teh C. P., Norhanis Razalli, Nithiyaa Nilamani, Zulfigar Yasin

Observations & Preliminary Results

➢ Survival rate of oyster larvae (from different populations) in different pH

Day 5

![Graph showing larval survival (%) vs pH for different broodstock populations.](graph.png)
Inherent adaptation

_Benthic organisms surviving in this current “extreme” area may display the “Positive Carry-over effect”_ quoting Pauline Ross (12 Dec 2012)

Species from this area may be a good target species for aquaculture in SEA?

Legend
Ocean Acidification is a Concern for Many Commercially Important Species

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>Molluscs</th>
<th>Echinoderms</th>
<th>Crustaceans</th>
<th>Finfish</th>
<th>Corals</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Molluscs" /></td>
<td><img src="image2.png" alt="Echinoderms" /></td>
<td><img src="image3.png" alt="Crustaceans" /></td>
<td><img src="image4.png" alt="Finfish" /></td>
<td><img src="image5.png" alt="Corals" /></td>
<td></td>
</tr>
</tbody>
</table>

Current estimated global commercial value

<table>
<thead>
<tr>
<th>Species Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molluscs</td>
<td>$24 billion</td>
</tr>
<tr>
<td>Echinoderms</td>
<td>$0.7 billion</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>$37 billion</td>
</tr>
<tr>
<td>Finfish</td>
<td>$65 billion</td>
</tr>
<tr>
<td>Corals</td>
<td>$30-375 billion</td>
</tr>
</tbody>
</table>

Sensitivity (percent of species affected)

- Positive
- None
- Negative

Feely et al., in prep.
WESTPAC Workshop on Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems

Phuket, Thailand 19 Jan 2015 - 21 Jan 2015
That was the consensus of 40 experts who gathered in Phuket, Thailand from 19-21 January 2015 to determine concrete actions they could take to help clarify and publicize the threats posed by ocean acidification, as well as to advance regional research capabilities and encouraging long-term monitoring of this trend in the Western Pacific and adjacent regions.
Autonomous Reef Monitoring Structures (ARMS) are a systematic tool to assess and monitor changes in indices of biodiversity. Ongoing development of both taxonomic and genetic analytical approaches to robustly detect biodiversity shifts.
NSF PIRE: Assembly of Marine Biodiversity along Geographic and Anthropogenic Stress Gradient
Bryozoan Tunicate
Cnidarian Poriferan
Bivalve Worm
Foram
Empty
Scuzz
Functional Groups
South East Asian Regional-GOOS

Development of Ocean Acidification Monitoring and Network
In the WESTPAC Region
PROJECT OBJECTIVES AND EXPECTED OUTCOMES:

- To understand the situation of ocean acidification (OA) level in the region and its status when compare to the global level, which could help to understand trend of ocean acidification and its impact to marine ecosystem in future.

- To increase capability on OA research and introduce the standard methodological study of OA into the WESTPAC region which will help the researcher who work in OA field could compare the data and information and exchange their knowledge and experience to build up their expertise including contribute to the global OA research community.

- To encourage the researcher in the region to aware an impact of OA to marine ecosystem in the region and establish the network to work together in the region and join with the global OA network.
Expected outcomes

1. The establishment of OA observation network at the regional level and join afford to with OA global network to make more understand on the situation of impacts of OA to the ecosystem at the Global level.

2. The figure of status of OA in the region and its relation to the marine ecosystem will be received including projection of its change and marine ecosystem impacts in the future base on the projection of IPCC and other related information.

3. The development of science and technology transfer to the marine scientific community in the region will be increase
Expectation from participation member countries:

- Active participate and implement the OA activities at their institute by their own support.
- Cooperation with other partner in the countries that working on OA
- Searching for fund to support their OA project and travel to join the project activities beside the support from the OA project
RECOMMENDED MEMBERS FOR THE PROJECT STEERING GROUP:

• Dr. Somkiat Khokiattiwong (Thailand) – Project proposer
• Dr. Suchana Chavanich (Thailand)
• Dr. Zainal Ariffin for consultation (TBC)
• Dr. Anastasia Tisiana for consultation (TBC)
• Prof. Aileen Tan Shau Hwa (Malaysia)
• Represent of Philippine (TBC)
• Dr. Rusty Branard (USA)
• Dr. Libby Jewett (USA)
• Dr. Weidong Yu for consultation (TBC)
• Dr. Vo Si Tuan – for consultation (Vietnam)-TBC
Thank you for your attention
Expected to get fund to support the Project:

- Receive technical support from NOAA through the cooperation of IOC-WESTPAC and NOAA
- Receive in cash or in kind support from participating member countries (potential from Thailand to provide capacity building, … ……..)
- Receive minimum or basic (technical support and some assistance, …) support from IOC-WESTPAC