

## OLI Final Project Report

### *Project Title:*

### *Effect of multi-scale oceanographic processes on coral reefs in the Andaman Sea*

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What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)

The primary question is how coral growth is influenced by temperature and oxygen variability in the region, which is modulated by unique multi-scale processes ranging from large-scale atmospheric and oceanographic forcing to regional high-amplitude internal waves and further down to local circulation and mixing regimes? The focus of our study has been on the role of large amplitude internal waves for the health of coral reef systems. The Thai coast of Andaman Sea was selected for this study due to the pronounced high-amplitude internal wave activities in the region (Fig. 1).

What have you discovered or learned that you didn't know before you started this work?

Most of previous studies have not integrated oceanography and reef ecology. Our study looked at the system as a whole, linking far-field oceanographic processes and near-field reef ecology. This has led to an interesting discovery in terms of the potential role of shelf system in modulating the effect of internal waves. This modulation is critical for coral health due to the co-existence of positive (cooling and nutrient enhancement) and negative (low pH and low oxygen) effect of internal-wave-induced upwelling of bottom water. Our results suggest a new hypothesis: A 'Goldilocks effect' for coral growth may exist, such that shelf-filtered internal waves are strong enough for thermal relief and enhanced productivity but not too strong for corals to be negatively impacted by low pH and O<sub>2</sub>.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?

The coral research community started to notice that corals suffer lower levels of mortality during bleaching events if exposed to large amplitude internal waves due to its cooling effect, implying that coral reefs in the internal wave regimes could survive ocean warming. However, our study suggested that cooling is probably not the whole story. High nutrient concentrations associated with internal-wave-upwelled water have a potential to create a favorable nutritional environment for coral to resist heat stress. Our study highlighted that more oceanographic, biogeochemical and physiological investigations are needed in future studies to fully understand the role of oceanographic processes for the coral reef ecosystem.

### What is the significance of this research for society?

Coral reef ecosystems harbor an estimated 25% of all marine species, support the livelihoods of over 500 million people worldwide, and protect thousands of kilometers of coastline from waves, storms and tsunamis. Yet coral reefs face extraordinary pressures both locally, through tourism, pollution and exploitation of reef resources, and globally through effects of climate change. While management of local stressors is an important and necessary conservation strategy, ocean warming and acidification threaten even the most well-managed reef systems. One practical approach to improve the chances of coral reef survival through the 21<sup>st</sup> century is the identification of refugia, coral reefs that stand the best chance of surviving an increasingly hostile ocean climate. Our study is a first step to explore the idea that coral reef ecosystems located within internal wave (IW) regimes are potentially important yet understudied climate change refugia.

### What were the most unusual or unexpected results and opportunities in this investigation?

The most unusual results from this study are:

- 1) Persistent stratification in the shallow near-shore sites even with strong mixing by internal waves and surface wind forcing (see an example of CTD data in Fig 1). This might imply that internal waves could potentially bring offshore high-density water near the bottom boundary layer, which is a great opportunity to investigate non-linear processes of internal-wave-induced material transport.
- 2) Enhanced plankton biomass in the near-shore sites (see an example of diatom abundance from VPR measurements in Fig 2), suggestion the impact of internal wave on the primary production in an oligotrophic environment. This offers an opportunity for a further investigation about the role of internal wave on nutrient enrichment and primary and secondary production.

### What were the greatest challenges and difficulties?

High-frequency internal waves are difficult to measure. Traditional ship-based measurements can only capture a snapshot of physical, biological and chemical properties of water column affected by the propagation and breaking of internal waves. Therefore, high-resolution and autonomous moored-measurements would be needed to augment ship-based station or transect measurements.

### When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)

We conducted two cruises in the Thai coast of Andaman Sea. In the original proposal, we only planned for one cruise in April 2015. During that cruise, we conducted both far-field oceanographic survey and near-field coral reef study. For the far-field survey, we collected high-resolution data on the vertical and horizontal distribution of plankton abundance, biomass, size, and taxonomic composition in relation to environmental variables including temperature, salinity, nutrients, pH and oxygen. We used a combination of sampling methods, including high-resolution Video Plankton Recorder (VPR) tows, net tows, and CTD casts, along two transects one from Similan Island, and the other from Racha, seaward to the middle of the Andaman Sea basin. For the near-field coral reef study, we collected coral skeletal and tissue samples from multiple reef-building species from key selected coral reefs on the Andaman Sea shelf, and measured water chemistry parameters near the coral sites.

Thanks to the support of our international collaborators at Thailand-China Joint Laboratory for Climate and Marine Ecosystem, we were able to join another cruise in April 2016 and collected the second set of far-field oceanographic data. This time, in addition to the tools we used in the first cruise, we deployed an eco-sounder, an temperature string and a bottom-mounted current meter to better capture the dynamics of internal waves propagating across the shelf.

#### What were the key tools or instruments you used to conduct this research?

We deployed Video Plankton Recorder in both cruises. The VPR is an ideal and efficient tool for evaluating the biological and physical fluctuations at high temporal and spatial resolutions. For the assessment of coral growth, a submersible coring drill was used to remove cores from selected coral sites. Automated programs developed in the Cohen lab was used to quantify skeletal growth and calcification rates, and coral energetic reserve from 3-D CAT scan data and photographs of sections through the tissue, respectively.

#### Is this research part of a larger project or program?

No, it's not. However, we are working on expanding this research into a larger NSF-supported project. Based on the data we collected and new hypotheses we developed through this OLI project, we have developed a pre-proposal to NSF PIRE (Partnership Partnerships for International Research and Education). If successful, we will have a significant funding support to implement a multi-nation multi-disciplinary research program over the next few years (See below for the next steps).

#### What are your next steps?

We are currently pursuing a large NSF-PIRE funding support. It will involve collaboration with scientists from Thailand, China, Germany and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) Sub-Commission for the Western Pacific (WESTPAC). If successful, this will allow a unique research and education opportunity and focus on this problem of global significance. The work will 1) advance our understanding of the physical dynamics of internal waves propagating through shelves and consequences for biological and chemical processes; 2) close knowledge gaps on eco-physiology of coral responses to multiple environmental stressors; and 3) provide scientific framework in identifying coral reef refugia and mapping potential sites for protection and conservation.

#### Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

We have recently submitted 3 abstracts to the 10th WESTPAC International Scientific Conference. The results and analyses to be presented in the meeting will be used for scientific journal publications. The conference abstract citations are:

Middleton, J.E., A. Cohen, R. Ji, H. Barkley, C. Davis, S. Khokiattiwong, G. P. Lohmann, L. Putchim, Z. Wang, W. Yu, and W. Zhang, 2017. The Role of Large Amplitude Internal Wave in Mitigating Impacts of Ocean Warming on Coral Reefs. 10th WESTPAC International Scientific Conference, Qingdao, China.

Wang, Z., R. Ji, W. Yu, S. Khokiattiwong, C. Davis, W. Zhang, and A. Cohen, 2017. Multi-scale effects of internal waves on carbonate chemistry and biology in the Andaman Sea. 10th WESTPAC International Scientific Conference, Qingdao, China.

Zhang, W. A. Cohen, C. Davis, R. Ji, S. Khokiattiwong, Z. Wang, and W. Yu, 2017. High-frequency internal waves, connecting the open ocean variability to shelf processes and coral reef biogeochemistry. 10th WESTPAC International Scientific Conference, Qingdao, China.

Please provide photographs, illustrations, tables/charts, and web links that can help illustrate your research.

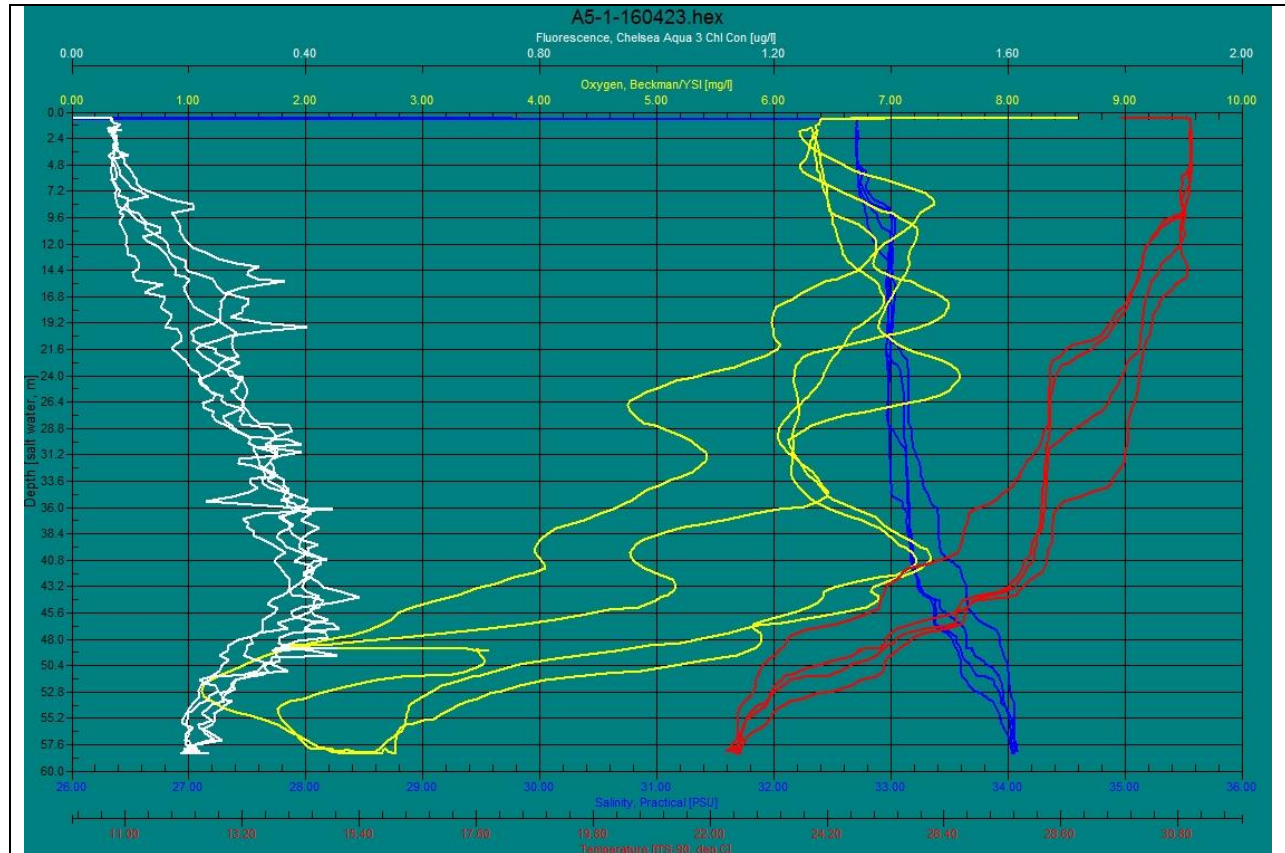


Figure 1. CTD measurements of Temperature (red), Salinity (blue), Oxygen (yellow) and Fluorescence (white) at a shallow site (bottom depth of 60 m) near Similan Island, where large amplitude internal waves are visible from the temperature differences between the up- and down-casts of CTD. The surface mixed layers is about 15-m thick, and the remaining water column is not well mixed.

Rod-shaped Diatoms (#/L) on Density ( $\sigma_t$ ), Sta A5, VPR18, May 3, 2015

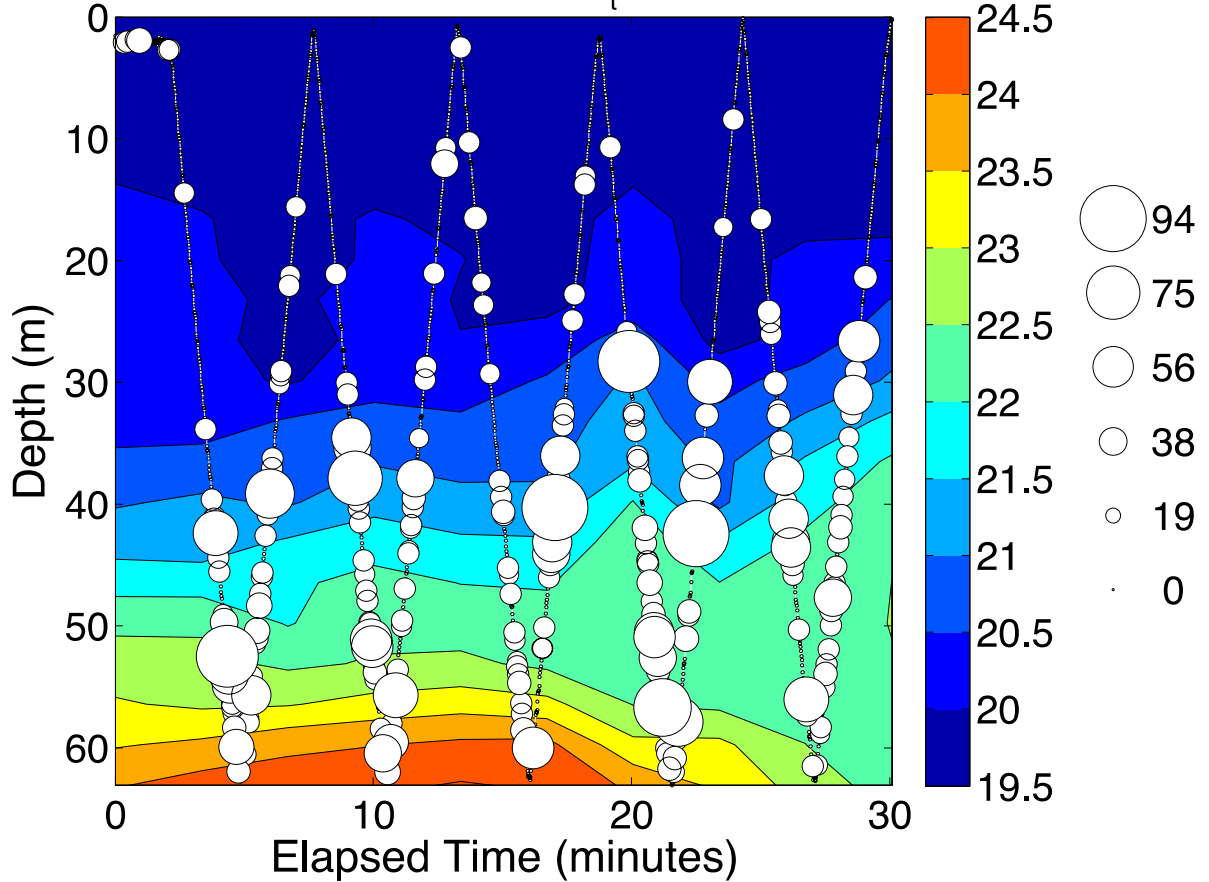


Figure 2. VPR measurements of rod-shaped diatom at a shallow site (bottom depth of 60 m) near Similan Island. The enhanced biomass can be observed mainly at the subsurface layer.