タイランド湾におけるサンゴ礁白化現象とサンゴ群集回復に関する研究

Impacts of Coral Reef Bleaching Events and Recovery of Coral Communities in the Gulf of Thailand
タイランド湾におけるサンゴ礁白化現象と サンゴ群集回復に関する研究

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Abstract

Mass coral bleaching events have been reported for over three decades worldwide and have increased in frequency, intensity and geographical region, caused by seawater temperature anomalies. The main objectives of this dissertation research are to quantitatively study on impacts of the coral bleaching events on coral community structure in different parts of the Gulf of the Thailand and to investigate recovery of certain coral communities after the coral bleaching events.

A severe coral reef bleaching event occurred in late summer 2010 in the Gulf of Thailand and the Andaman Sea. Most coral colonies in Thai waters were affected by the coral bleaching event. The proportion of bleached coral colonies in the Inner Gulf of Thailand, the Western Gulf of Thailand and the Andaman Sea were 61%, 91% and 97%, respectively. There were significant differences in the impact of the coral bleaching event among coral species and study sites. The bleaching severity in *Porites lutea*, a species found on belt-transects at all study sites, showed lower severity of bleaching at the study sites in the Inner Gulf of Thailand.

A long-term study of coral reef ecology in the Gulf of Thailand provides a good opportunity to examine the temporal variation on the impact of mass coral bleaching at certain reef sites. The bleaching and mortality of corals between the mass bleaching events in 1998 and 2010 at a coral community in the Western Gulf of Thailand were compared. Levels of bleaching were significantly different between the most dominant corals. *Diploastrea heliopora* was the most resistant coral to bleaching in both years. Some coral species showed more resistance to bleaching in 2010. The coral mortality following the mass bleaching events in 1998 and 2010 varied significantly between the years and the coral taxa. Mortality of some dominant coral taxa was also lower in 2010. Nine coral species; *Astreopora myriophthalma*, *Pachyseris rugosa*, *Turbinaria mesenterina*, *Goniastrea pectinata*, *Favia*

pallida, *F. maritima*, *Favites halicora*, *Platygyra daedalea* and *Galaxea fascicularis*, were partially tolerant to the coral bleaching events.

The impact of elevated water temperatures in May-August 2010 on coral assemblages at Kut Island, in the eastern Gulf of Thailand was assessed by quantifying the changes of live coral cover before and after the 2010 bleaching phenomenon at three study sites. The coral mortality as a result of the bleaching varied significantly among the three study sites. Corals at Ao Kralang had the highest percentage of mortality (45%) whereas Ao Phrao had the lowest (26%), the latter site being subject to relatively high water-flow. Substantial differences in mortality were found among coral taxa. Fungiids showed the lowest percentage mortality (<5%) while all observed colonies of *Montipora* spp., *Acropora* spp. and *Pocillopora damicornis* completely died. Recovery of these corals will depend on recruitment from neighbouring reefs where some surviving colonies were observed.

Surveys at three sites at Kut Island in the eastern part of the Gulf of Thailand revealed that before the 2010 bleaching event took place, live cover of *Acropora* was very low (0.35-1.46%) and even decreased to 0.1% afterwards. Only *A. millepora* colonies were affected. The low *Acropora* coverage at the study sites before the event was still a result of the previous massive coral bleaching in 1998. Densities of juvenile *Acropora* colonies before the 2010 bleaching event were also very low at the study sites (on average 0.01-0.03 m^{-2}), with no recruitment for up to nearly two years. Several *Acropora* species that were previously found at Kut Island are presently at risk for local extinction or may already have disappeared.

The comparison of coral community changes after the 2010 coral bleaching event between the deep pinnacle at Hin Gurk Maa and the shallow reef at Ko Yak, in the Eastern Gulf of Thailand revealed that before the coral bleaching event, live coral covers at both study sites were nearly the same (about 72%). However coral mortality after the bleaching event at Ko Yak (62.0%) was significantly higher than Hin Gurk Maa (31.2%) (t-test, $p<0.05$). The cover of *Acropora* spp., *Montipora* spp., *Pavona frondifera* and *Pocillopora damicornis* at both study sites decreased significantly following the bleaching event. The densities of coral recruits at both study sites were not significantly different but a higher diversity was observed at Hin Gurk Maa. Several coral species in the Eastern Gulf of Thailand that are high local extinction probabilities were determined: *Acropora* spp., *Favites complanata*, *Goniastrea pectinata*, *G. retiformis*, *Herpolitha limax*, *Platygyra pini*, *Plerogyra*

sinuosa, *Pocillopora damicornis* and *Montipora* spp. Coral communities on several deep pinnacles in the Gulf of Thailand may act as important refugia for coral survival following the bleaching events.

The assessment of coral reef resilience to climate change is an important task but has been difficult to carry out because of a lack of empirical scientific data. Coral reef resilience at twenty study sites in Thai waters was quantitatively assessed, approximately two years following the 2010 severe bleaching event, based on the percentage of non-bleached coral colony, the percentage of surviving coral colonies and the density of juvenile corals. Coral reef resilience varied greatly among the study sites and major reef groups according to their community structure, largely due to the differing bleaching resistance and tolerance of the dominant coral species. Most study sites in the Gulf of Thailand had much lower coral recruitment rates compared to other reef sites in Thai waters. The study sites in the inner Gulf of Thailand had the highest resilience while the study sites in the Andaman Sea had the lowest. The maximum seawater temperatures recorded by HOBO data loggers during the bleaching event in 2010 were 32.7°C at Ko Khrok, in the inner Gulf of Thailand and 33.3°C at Mu Ko Surin, in the Andaman Sea.

The ability of coral reefs to recover from natural and anthropogenic disturbances is highly influenced by the pattern and strength of connectivity among populations through dispersal of planulae which are very variable. Population genetic studies provide important information that can be applied for managing marine protected areas and their networks. Knowledge of genetic connectivity is useful for understanding of the recovery potential of coral populations after various disturbances, such as mass coral bleaching. Population genetic patterns in the coral *P. damicornis* at twelve locations in the Gulf of Thailand were investigated by using microsatellite markers. The results showed high genetic similarity among populations over 300 kilometers apart. This may be the consequence of long competency periods of brooded zooxanthellate larvae and multiple larval release events each year. Therefore, high levels of connectivity appear to be maintained between reef sites in the Gulf of Thailand for brooded corals.

A coral reef management and restoration project in tourist hot spots in the Gulf of Thailand was initiated and funded by the network of provinces in eastern Thailand. The projects aimed to survey and established an ecological and socio-economic database for

managing the coral reefs and enhance their resilience to climate change. In addition, artificial substrates for coral recruitment and ecotourism were provided at tourist hotspots with the participation of local communities in managing natural resources and environment, wherein public awareness and education were enhanced. The project involved effective collaboration between scientists, local communities and local government officials as decision-makers to integrate scientific data into policy and adaptation measures. The coral reef restoration sites can be used in the future to support ecotourism and learning opportunities for students. Continuing efforts in capacity building, public awareness and education through disseminating printed materials and conducting training courses, workshops and seminars for stakeholders, youth, students and local government officials can enhance resilience in coastal communities. This project applied Thailand's coral reef restoration plan which comprises 4 strategies and 15 measures and focuses on passive restoration by reducing threats from tourism, water pollution, sedimentation and fisheries. Strengthening the long-term monitoring, evaluation and reporting of the project can provide lessons for conservation of coral reefs in tourist hotspots influenced by climate change, especially coral bleaching events. A list of research topics needed to cope with coral bleaching in Thai waters is provided.