学 位 論 文 の 要 旨

論文題目 **Seasonal dynamics influencing coastal primary production and phytoplankton communities along the southern Myanmar coast**
（季節性動的要因がミャンマー南部沿岸の海洋基礎生産と植物プランクトン群集に与える影響）

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Chapter 1: GENERAL INTRODUCTION

Myanmar (The Republic of the Union of Myanmar) stands as the 10th position among the world fish producing countries in 2010 and the 3rd position in ASEAN (FAO, 2015), with the production of over 2.3 million tons in marine capture fisheries. The Myanmar coastline stretches about 3,000 km and is characterized by wide and numerous rivers, forming large and small deltas, estuaries, and extensive mangrove creeks. Myanmar has diverse tropical monsoon climate and its coastal areas are influenced by strong monsoon regimes; southwest monsoon (rainy season) and northeast monsoon (dry season). For the sustainable capture fisheries, the key mechanisms and the characteristic environments supporting such high fish catches should be investigated, however, very few survey have been conducted in the Myanmar coastal areas so far and this fact leads to the lack of appropriate conservation or regulation in the coastal fisheries.

In this thesis, seasonal primary productivity off the foremost fisheries ground, Tanintharyi coast, was investigated for the first time in the Myanmar coasts. In the surveys, instead of using conventional bottle incubation methodologies using carbon isotopes, primary production estimation was performed using a principle of the pulse amplitude modulation (PAM) fluorometry. In Chapter 2, efficacy of this new methodology was primarily investigated in the laboratory incubation experiments using several phytoplankton cultures and natural seawaters containing natural phytoplankton assemblages. In Chapter 3, by applying this new PAM fluorometry, and with other conventional oceanographic surveys, the mechanisms of the coastal primary production off Myeik City was surveyed in three distinct seasons and at sampling stations covering characteristic coastal environments. In Chapter 4, occurrence lists of the phytoplankton species were made with numerous microphotographs, and they were discussed in connection with the primary productivities and the environments. In the last chapter, Chapter 5, the general discussion was given based on the results obtained in the previous chapters and led possible mechanisms controlling the coastal primary production, with emphasizing the effect of environmental deteriorations.

Chapter 2. EFFICACY OF THE PULSE-AMPLITUDE-MODULATION (PAM) FLUOROMETRY IN MEASURING PRIMARY PRODUCTIVITY USING CULTURE STRAINS OF PHYTOPLANKTON SPECIES AND FIELD WATERS

Estimation of the electron transport rate (ETR) in the plant photosystem II (PSII) can be achieved in a PAM fluorometry, and the ETR is known to be a good proxy of the actual carbon fixation. In this chapter, the efficacy of the PAM fluorometry for measuring photosynthetic rate in

phytoplankton was investigated using several diatom strains isolated from the Myanmar and Japan coasts and also natural seawaters obtained from the Seto Inland Sea in various seasons. The results showed there were good linear regressions between the actual O_2 evolutions and ETR based O_2 evolutions ($R^2 > 0.77$) in the culture experiments and ($R^2 > 0.64$) the field trials, evidencing the efficacy of the PAM fluorometry in any types of phytoplankton assemblages, locations, and seasons. From the result, the ETR based O_2 evolutions were overestimated due to overestimation of the theoretical value (4 e^- = 1 mol of O_2). The resulted ETR to O_2 conversion rates were 7.01 in the incubation experiment using culture strains and 11.83 in the incubation experiment using field water. In this research, their mean value 9.42 was applied in the estimation of primary productivity and later compared with the reported value of Goto et al. (2008).

Chapter 3: PRIMARY PRODUCTION OFF MYEIK CITY, SOUTHERN MYANMAR COASTAL AREA

Field surveys off Myeik City, Tanintharyi region, were conducted for the first time. To understand the effects of environmental contributions, particularly unique climate characters of Myanmar to the productivity, surveys were conducted thrice: at the onset of the dry season (December, 2014), the end of the dry season (March, 2015) and the rainy season (September, 2015). 13 sampling stations were set around Kadan Island, off Myeik City, covering the areas of estuaries, mangrove channels or creeks, and offshore region facing the Andaman Sea.

The lowest surface salinity value (7.11) in the rainy season indicated this area was largely affected by river inflow, and as a result, nutrient concentrations were high especially SiO_2-Si and DIN-N. However, PO_4-P concentration showed different trend which might be supplied by different mechanisms rather than river inflow, probably from the bottom sediments.

The most notable feature of the ocean production was the well-defined seasonality, which has not previously been recognized as a typical model in a tropical ocean system (Cushing 1959). According to the estimations employing the PAM fluorometry, the primary productivity was highest in the dry season, 2.59 ± 1.56 g C m^{-2} d^{-1}, while the productivities were low at the onset of the dry season and the rainy season (1.36 ± 0.77 and 0.17 ± 0.11 g C m^{-2} d^{-1}, respectively). When the resulted productivity values were recalculated by incorporating observed O_2/ETR ratios (0.117 under PFD<500 μmol photon m^{-2} sec^{-1}, or 0.073 under PFD>500) in Goto et al. (2008), the annual primary productivity was estimated as 129.6 g C m^{-2} yr^{-1}, which is unexpectedly lower than the candidate values (300 – 500 g C m^{-2} yr^{-1}) obtained from the world eutrophic estuarine and coastal ocean ecosystems (Nixon 1995).

Based on the principal component analysis (PCA), the primary productivity negatively correlated with the extensive river inflows, especially in the rainy season, where the turbid river water inflows deterred the primary productivity. High primary productivity at the end of dry season related with the increase of euphotic layer depth, probably due to approach of oceanic water as well as decrease of the river water inflows and this was the main factor promoting primary productivity in this season.

Interestingly, low coastal primary productivities might be compensated by microbial food chain. High DOC concentrations (average 7.48 ± 4.22 mg L^{-1}) at the onset of the dry season probably led to abundant bacterial populations (average bacterial density = 1.1 × 10^7 cells mL^{-1}). The estimated bacterial biomass of this season was 3 times higher than the estimated phytoplankton biomass.

Chapter 4: PHYTOPLANKTON OCCURRENCE OF OFF MYEIK CITY, EMPHASZING ON THE CHARACTERISTICS SEASONALITY OF THE COAST

During the surveys, the phytoplankton communities were mostly populated by diverse diatom species, especially chain-forming species, indicating that the areas appear to possess stable ground of

the food chains. The end of the dry season, when it was recognized as being the most productive period, showed dominant occurrence of the chain-forming diatom *Bellerochea horologicalis*. This species was also found throughout the seasons. *B. horologicalis* is the species often related with highly turbid water and eutrophic coastal water, which further suggests the extensive effect of the turbid river waters throughout the year. Benthic diatoms, e.g. *Pleurosigma normanii* and *Bacillaria paxillifera*, which were assumed to be originated from the mangrove sediments, also occurred abundantly in the water columns and played roles in the primary production. *Thalassionema nitzschoides*, a ubiquitous diatom occurring throughout the season, is known to dominate mangrove creeks in the worldwide estuaries, and this fact also implied importance of mangrove forests to the coastal productivity.

Chapter 5: GENERAL DISCUSSION

Through the results obtained in the previous chapters, the seasonal trend of primary productivity and controlling environmental factors near the Myeik City were clarified for the first time. The main primary producers were the chain-forming diatoms associated with euhaline and eutrophic natures. Their production was primarily driven by the characteristic monsoon climates and showed well-defined seasonality; the end of the dry season was the most productive period, while the onset of the dry season and the rainy season remained in significantly lower productivities, 52.5% and 6.6% of that at the end of the dry season. These drops in the productivities for more than half of a year led unexpected low annual primary productivity (129.6 g C m^{-2} yr^{-1}). The long rainy season that delivered heavy precipitation and extensive river runoff brought terrestrial nutrients to the coast, but as a trade-off, the coasts were largely affected by turbid waters, which decreased light penetration into the water column and thus reduced primary production. This highly turbid water was probably originated from soil erosion due to deforestations by industrial plantations along the Tanintharyi River Basin. Especially, deforestation of mangrove trees along the riverbanks and the estuaries seemed to be serious and was considered to lead to problems of soil erosion, because mangrove forests could reserve fluvial sediments as buffer areas for ocean- land interaction. Together with the findings that suggesting DOC derived from the mangrove sediment might enhance microbial food chain and supplement the primary production, conservation of mangrove forests is also needed to sustain the coastal productivity.