Functions of mangrove plants-roots and soil chemicals

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The soils of coastal areas in tropical and sub-tropical regions are often low in nutrients and therefore have low fertility. First, tidal fluctuations wash out considerable quantities of organic matter such as plant detritus into the ocean, leading to low nitrogen soils. Second, minerals necessary for plant growth, such as iron and phosphorus, tend to be adsorbed on soil particles and oxide complexes in tropical oxidized soils, and thus plants cannot uptake these immobilized minerals. Under such infertile growth conditions, how do mangroves get enough nutrients to correspond to their high productivity? This presentation focuses on functions of mangrove plants which are keys to the highly productive mangrove ecosystems-that is, what happens to soil chemical properties after mangrove plants colonize? In order to characterize mangrove ecosystems and provide scientific guidelines for their conservation, knowledge of their soil chemical properties is necessary, because these properties are the basis of the ecosystems.
When plant seeds germinate and start to grow, soil chemical properties are affected. It is known that plants excrete a variety of substrates that facilitate the availability of macro- and micronutrients in the root zone, by enhancing absorption of appropriate nutrients even under nutrient deficient conditions. For instance, organic acid exuded from plant roots, such as citrate and malate, are known to mobilize P from sparingly soluble Fe, Al and Ca phosphates. Therefore, greater amounts of nutrients such as P and Fe are sometimes observed in a plant root zone compared with the bulk soil. Besides root exudates, plant roots continuously provide organic matter such as decaying root parts. These organic matter-rich root zones are different from the bulk soil and provide niches in which bacteria thrive, because heterotrophic bacteria can use these plant-derived carbon compounds as electron donors to generate energy. Therefore, soil microbial metabolic processes also change in association with plant colonization.
So far, root exudates from four mangrove species (*K. obovata, B. gymnorrhiza, E. agallocha* and *H. fomes*) have been characterized. In field work, there are some reports that Fe^{2+} concentration in mangrove soil pore water is positively correlated with live root density. These observations indicate that mangrove roots lead to enhanced Fe mobilization. We conducted a pot experiment and found that *A. marina* has high ability to move Fe and P in soil pore water, suggesting that mangrove roots provide Fe- and P-solubilizing substrates. In the pot experiment, we also found that three mangrove species (*A. marina, R. stylosa* and *B. gymnorrhiza*) have a function to enhance soil nitrogen content. During the six months' cultivation period, amounts of nitrogen in the mangrove soils increased four times more than in uncolonized soil. At the end of the cultivation, bacterial nitrogen fixation was significantly higher in the mangrove soil than in uncolonized soil, leading to an interpretation that the mangrove plants induced nitrogen fixing bacteria around them.
These self-supporting abilities observed in mangroves could be key functions so that they can form highly productive ecosystems even under sterile environments. There are more functions in mangroves that we do not yet know, so there is much more to discover.

キーワード：マングローブ植物、根の機能、土壌化学
Keywords: mangroves, root function, soil chemicals

海草藻場における炭素隔離・貯留過程の解析
Carbon sequestration and storage in seagrass meadows

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Seagrass meadows are one of the most productive ecosystems and play an important role as carbon reservoirs, storing large amount of organic carbon in the sediments. Estuaries are considered to be a net source of atmospheric CO_2 due to the mineralization of terrestrial carbon but recent studies demonstrated that seagrass meadows in estuaries can be sinks for atmospheric CO_2. The flow of organic and inorganic carbon derived from multiple sources regulates these processes but the knowledge about these relationships is limited. In this study, we evaluated the flow of carbon derived from multiple sources in seagrass meadows using isotopic approaches and associated the flow with the processes of both atmospheric CO_2 uptake and carbon storage in sediments. We estimated the contribution of atmospheric CO_2 to assimilated seagrass carbon by a carbon-source mixing model using radiocarbon concentrations ($\Delta^{14}C$). The model indicated that the seagrass assimilated 0–40% of its inorganic carbon as atmospheric CO_2. The stable isotopic signatures ($\delta^{13}C$ and $\delta^{15}N$) of both particulate organic carbon (OC) and sedimentary OC suggested that the efficiency of OC storage in sediments would be dependent on OC derived from multiple sources. We will also present the historical changes in carbon storage using sediment core analyses.

キーワード：海草藻場、炭素貯留、同位体分析、堆積物、有機炭素
Keywords: seagrass meadows, carbon storage, isotopic analyses, sediment, organic carbon

温帯性サンゴによる生理学的応答の季節変動
Seasonal variation of physiological response by temperate zone corals

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Rising temperature has resulted in a poleward shift/expansion of corals in Japan (Yamano et al., 2011). However corals at high latitude are confronted to environmental conditions that differ from tropical conditions with lower temperature in winter, lower light levels, higher nutrients concentrations, etc. Moreover due to the increase in CO_2, aragonite saturation state of the ocean is decreasing (Kleypas, 1999) and this trend may counter the expansion of corals. We conducted chamber experiment at Shimoda located on the tip of the Izu peninsula, Shizuoka, Japan. To understand the influence of seasonal variation on the physiological response (such as photosynthesis, respiration, calcification, antioxidant enzyme activities, etc.) of temperate corals, colonies of *Porites heronensis* and *Alveopora japonica* were transplanted in the field. Every three months for 1.5 year, three colonies of each species are sacrificed: their metabolisms is first measured in situ and then different physiological parameters are measured. Bleaching during winter was observed for both species. In winter, bleached *A. japonica* and *P. heronensis* showed reduced metabolic rates compared to summer. Once the temperature re-increased, all colonies of *A. japonica* recovered and all except one *P. heronensis* recovered. Antioxidant enzyme superoxide dismutase (SOD) in host coral of both *A. japonica* and *P. heronensis* also clearly increased in summer and decreased in winter.
In *P. heronensis* the mitochondrial electron transport activity per protein ratio was higher in summer than in winter and the zooxanthellae mitotic index reached values as high as 30% during the warmer months. These observations suggest that *A. japonica* is resilient to low temperature with a high chance of recovery after bleaching whereas *P. heronensis* compensate for the reduced growth rates in winter with a highly active metabolism and high growth rate in summer.

キーワード：温帯性サンゴ、代謝変動、低水温白化
Keywords: temerate zone corals, metabolic changes, cold temperature bleaching

サンゴポリプ内における褐虫藻の個体群動態と活性酸素種の動態を基にしたサンゴの白化現象のモデル化
Modeling coral bleaching based on dynamics of zooxanthellae population and reactive oxygen species inside a coral polyp

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Coral bleaching is a phenomenon in which corals expel/digest a large amount of their symbiotic algae (zooxanthellae), and it is caused by some stresses, e.g., thermal stress. In the summer of 2016, mass bleaching induced by higher seawater temperature and resultant mass mortality had catastrophically damaged coral communities on many coral reefs all over the world. Such mass bleaching events will likely occur more frequently in near future due to global warming. But the reason and mechanism of the bleaching are still unclear. Therefore, for projecting near future status of coral communities precisely, it is important to elucidate the bleaching mechanism and to develop a numerical simulation model.
It is observed that corals expel zooxanthellae even under normal thermal conditions (e.g. Hoegh-Guldberg et al., 1987). The number of zooxanthella cells increases due to reproduction, but the zooxanthellae density in the coral tissue is kept around the order of 10^6 cells cm^{-2} under normal thermal conditions. Therefore, it is considered that the zooxanthella density of ~10^6 cells cm^{-2} is optimal and coral is controlling the density to be an optimal value by expelling zooxanthellae. Now, how is the coral determining the optimal value of zooxanthella density? Zooxanthellae produce photosynthate which is an important energy source for corals, but these also produce reactive oxygen species (ROSs), which damage coral cells, through their photosynthesis (e.g. Weis 2008). It is considered that corals basically want to keep the density of zooxanthellae as high as possible for improving photosynthate availability. But when the zooxanthella density increases, the concentrations of harmful ROSs also increase in the coral cells because of zooxanthellae ROS production. Therefore, coral may control zooxanthella density for keeping ROS concentration within tolerable levels by expelling/digesting zooxanthellae. Additionally, it is reported that the production rate of ROS increases with increasing light intensity and temperature (e.g. Saragosti et al. 2010; McGinty et al., 2012). When temperature increases, ROS release rate per individual zooxanthella cell also increases, then the ROS concentration increases. Thus, corals have to decrease zooxanthellae density for keeping the ROS concentration at tolerable levels. This is our hypothesis for the coral bleaching mechanism. In this sense, the bleaching action might be an emergency measure of corals.
Based on this hypothesis, coral bleaching model was developed based on the coral polyp model (Nakamura et al., 2013) by incorporating both ROS dynamics and zooxanthella population dynamics. The ROS dynamics includes light and temperature dependent ROS release process and detoxification of ROS by antioxidant substances, and the zooxanthella population dynamics includes processes of reproduction, mortality, and expelling/digesting rates that depend on the ROS concentration in the coral cell. These dynamic processes are linked with coral internal environments reproduced by the coral polyp model.
Results of simulated 30 day incubation experiments under different temperature conditions by the bleaching model well reproduced coral bleaching phenomenon dependent on temperature. Moreover, it is notable that the simulation result under a higher incubation temperature for first 5 days followed by

incubation under normal temperature for 25 days well reproduced recovery process following bleaching process. It is one of very unique features of this model.
Moreover, the bleaching model was coupled with a hydrodynamic-biogeochemical model based on the Regional Ocean Modeling System (ROMS; Shchepetkin and McWilliams 2005), and the coupled model system was applied to the Shiraho coral reef, Ishigaki Island, Japan. From these results, it was confirmed that the zooxanthella density decreases with increasing offshore temperature, and clear spatial variation was confirmed that coincided with spatial variation of water temperature inside the reef.

キーワード：サンゴの白化現象、数値シミュレーション、褐虫藻、活性酸素種
Keywords: coral bleaching, numerical simulation, zooxanthellae, reactive oxygen species

鉱物と掛り合う沿岸海洋：バイオマスによるサンゴ礁回復
Minerals in Coastal Ocean: Recovery of Biomass-stocking Coral Reefs

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大気二酸化炭素が溶け込んだ表層海水に鉱物・バイオマスは溶解する。酸・塩基解離の可逆的化学反応のメカニズムは石灰化を行う生き物の個体の発育、それらの群体への発展途上には不可欠である。しかし生物と無関係に当反応は海水中で起きる。表層海水の正体は、当反応に関わる各溶存イオン種の化学ポテンシャルの高低によって評価されるからである。大気二酸化炭素に対して開放系にも拘わらずその浅瀬海域は弱塩基を保持・維持している。尚大気下の淡水は酸性(pH < ~7)である。酸・塩基滴定実験を通して可逆的石灰化反応

$Ca^{2+} + HCO_3^-$ $CaCO_3 + H^+$

を10年前に偶然発見した。塩濃度（Salinity)によって石灰化反応メカニズムは異なる。海水中では上記の酸解離反応で、淡水では溶解・析出の物理反応$Ca^{2+} + CO_3^{2-}$ $CaCO_3$である。石灰化・脱石灰化の可逆的反応は酸解離反応でプロトン生成・プロトン消費の可逆反応でもある。表層海水の本性は、弱塩基範囲内に制御されたプロトン濃度のホメオスタシス（恒常性）機能を備えていることにある。しかし、人間活動による大気二酸化炭素濃度増加による海洋酸性化は鉱物溶解をもたらす。

石灰化化学反応の溶解度積 $[Ca^{2+}][HCO_3^-]$は$[H^+]$増加（pH降下）と共に増すので正味の石灰化速度は減少する。よって表層海洋の酸性化は当速度を減少させる。正味の石灰化速度は、海水中ではカルシウムイオンとHCO_3^-との溶解度積に反比例するので$[Ca^{2+}]$のpH依存性を評価しなければならない。尚 $[HCO_3^-]$のpH依存性は小さい。正味の石灰化速度の検討は、 $[Ca^{2+}]$のpH依存性の評価が不可欠であって水溶性炭酸塩化学の立場のみでは不充分である。カルシウムイオン濃度の供給源は、鉱物やバイオマスの海洋への溶出から期待される。サンゴ礁の生物多様性維持は重要であって、人間活動によるPCO2増加のみならず沿岸、サンゴ礁の魚類・貝類の漁獲量制限を検討しなければならない。 (K. I.: ichikawa@ees.hokudai.ac.jp)

キーワード：鉱物、沿岸海洋、サンゴ礁、回復能、バイオマス

キーワード：鉱物、沿岸海洋、サンゴ礁、回復能、バイオマス
Keywords: Mineral, Coastal Ocean, Coral Reefs, Recovery Potential, Biomass

造礁サンゴの遺伝学的解析による種分化とコネクティビティ解析
Genetic connectivity and speciation of reef-building coral

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高い生物多様性を有すサンゴ礁生態系は、気候変動に最も脆弱な生態系のひとつであり、現在世界中のサンゴ礁生態系は衰退傾向にある。日本国内では、最大のサンゴ礁海域である石西礁湖において、2016年に高水温により約7割のサンゴが白化し、保全策の検討が急務となっている。一方で、温帯域では海水温の上昇に伴い、亜熱帯域で絶滅危惧種として認定された造礁サンゴ複数種の生息分布域が北上していることが報告されている (Yamano et al 2011)。そのため、温帯域が亜熱帯域で危機的にあるサンゴの避難所として期待されている。しかし、北上したサンゴの北限分布域周辺の集団は、遺伝的多様性が低く、他海域からの加入量が限定されている場合、絶滅と加入を繰り返す不安定な集団である可能性もある。そのため、北上集団の遺伝的多様性や、幼生分散を通じた周辺集団との連結性を明らかにすることは、避難所としての機能役割を明らかにする上でも重要である。そこで本研究では、①サンゴの衰退が深刻である石西礁湖周辺の海域で回復に重要な幼生分散で繋がる集団同士を同定するため、および②分布北限域に新たに出現した集団の遺伝的安定性を調べ、避難所としての役割を明らかにするために、亜熱帯域でから温帯域まで幅広く分布している普通種であり、過去80年において北上しているクシハダミドリイシ、および熱帯・亜熱帯種であり近年北上が確認されたアオサンゴを対象とし、石西礁湖周辺海域および黒潮に沿った亜熱帯から温帯にわたる集団について高度多型遺伝子マーカー遺伝子座を用いた集団遺伝解析を行った。

アオサンゴでは、ベイズ法を用いたクラスタリング解析および核のITS2領域において、隠蔽的な種分化が起きていることが分かった。推定された2種（HC-AおよびHC-B）のうちHC-Bはサンゴ礁内のより温暖な環境を好み、もう片方のHC-Aは外洋に面したスロープなどの流速が早く、海水温が相対的に低い環境を好んでいた。2種は産卵期が約1ヶ月ずれているために同所的な海域でも交雑が限定されていることが分かった。個々の種内の遺伝子流動は非常に限られており、石西礁湖周辺海域では、石垣島の南西の海域を除き、ほとんどの集団間で集団が有意に分化しており、アオサンゴの短い幼生分散期間に起因すると考えられた。HC-Aは1990年代に初めて屋久島で最北限に分布する群体が3群体のみ見つかった。

クシハダミドリイシでは既存研究により、種内で異なる遺伝的クレードが存在していることが確認されている(Launder and Pulmbi 2012, Suzuki et al. 2016)。そのため、まず、日本国内の黒潮流域に存在する隠蔽的遺伝クレードの分布を明らかにした。ベイズ法を用いたクラスタリング解析により、クシハダミドリイシの遺伝的クレードの推定を行った結果、本解析では3つの遺伝的クレードが確認され、そのうちのひとつが温帯域まで分布していた。そのため、1つの系統については、温帯域が避難所となり得ることが示唆された。一方、屋久島以南と以北では遺伝分化係数が大きいため、直接の亜熱帯域から熱帯域への加入はあまり多くないと考えられた。石西礁湖内には、異なる2系統が存在することが確認された。石西礁湖周辺ではどちらの系統内でも、有意な遺伝分化係数を持っており、弱い遺伝構造をもつことが確認された。それぞれの系統で遺伝障壁を調べたところ、石垣島と石西礁湖の間および西表島南部の東西で両系統ともに遺伝障壁が現れたため、これらの海域を個々に保全することが有効であると考えられた。黒潮に沿った温帯域まで含む集団では、屋久島以北の集団は屋久島以南の集団よりも遺伝的多様性が低いこと、さらに過去40年で北上が認識された集団の遺伝的多様性は他の温帯域の集団よりも低く、環境変化に対しやや脆弱性を秘めている可能性が示唆された。一方ボトルネック検定では全ての集団において有意にならず、一度北上して加入してからは比較的安定した再生産を繰り返していることが示唆された。また比較的最近に北上してできた五島列島の集団は、周辺海域からの幼生加入の可能性が低く、クローン率も高いことから、太平洋側で北上しているが周辺集団と遺伝的組成の近い式根島よりも、地域絶滅した場合の回復には長い時間を要する可能性があると考えられた。

キーワード：サンゴ礁、コネクティビティ、遺伝子流動
Keywords: coral reefs, connectivity, gene flow

Evidence of chronic anthropogenic nutrients within coastal lagoon reefs, adjacent to urban and tourism centers, Kenya: A stable isotope approach

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The sources of anthropogenic nutrients and its spatial extent in three fringing reefs with differing human population gradients in Kenya were investigated using stable isotopes approaches. Nutrient concentrations and nitrate δ^{15}N in seepage water clearly indicated that population density in the catchment and tourism along the coast contributed greatly to the extent of nutrient loading through the groundwater to adjacent reefs in Kenya. Although water column nutrient analyses did not show any significant difference among the 3 studied reefs, the chemical contents (i.e., δ^{15}N and N contents) in the macroalgae and complementary use of seagrasses and sedimentary organic matter clearly indicated the different nutrient regime among the sites in higher special resolution. Higher δ^{15}N and N contents in macrophytes showed terrestrial nutrients affected primary producers at onshore areas in Nyali and Mombasa reefs, but were mitigated by offshore water intrusion especially at Nyali. On the offshore reef flat, where the same species of macroalgae were not available, complementary use of δ^{15}N in sedimentary organic matter suggested input of nutrients originated from the urban city of Mombasa. If population increases in future, nutrient conditions in shallower pristine reef, Vipingo, may be dramatically degraded due to its stagnant reef structure. This study represent the first assessment of the Kenyan coast that integrates water column nutrients and macrophyte δ^{15}N analyses, showing direct evidence of the use of terrestrial nutrients by macrophyte and providing basic information for surveying the link between anthropogenic enrichment and ecosystem degradation including macroalgae proliferation in nearshore reefs.

キーワード：人為起源物質、安定同位体比、ケニアサンゴ礁、大型藻類
Keywords: anthropogenic nutrient, stable nitrogen isotope, Kenyan coral reefs, macroalgae

西表島崎山湾におけるサンゴ分布の底面流速と土粒子量との関係
Relationship of coral distribution with bottom flow speed and soil particle quantity in Sakiyama Bay, Iriomote Island, Japan

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西表島崎山湾におけるサンゴ分布と物理環境との関係を明らかにすることを目的として，調査研究を実施した．まず，湾内72地点における群体形状別サンゴ被度分布と群集タイプ別サンゴ分布域の現地調査を行い，次に，湾域の夏季と冬季の平均的な気象場における数値シミュレーションによる海洋流速場と土粒子数分布の計算結果を解析し，現地調査で得られたサンゴ分布と比較した．

崎山湾では，卓状，葉状，被覆状サンゴは礁縁に，枝状サンゴは礁縁と湾口部に，塊状サンゴは湾口部から湾央部に，主に分布していた．サンゴの群体形状別の出現地点数と平均被度は，枝状サンゴが41地点において39%，卓状サンゴは28地点において15%，塊状サンゴは47地点において7%，葉状サンゴは19地点において6%，被覆状サンゴは25地点において7%であった．

崎山湾では，7か所の枝状サンゴ群集と4か所の卓状サンゴ群集が確認された．枝状サンゴ群集中のサンゴの枝の生きているところから頂点までの長さと根元の幅の平均値を元に，枝状サンゴ群集を長い枝状，短い枝状，短く細い枝状に分類した．長い枝状，短い枝状，短く細い枝状，卓状サンゴ群集の主な分布場所・群集数・面積は，それぞれ礁縁からやや湾内側に入った湾口部・2群集・16ha，波あたりの強いリーフ上・4群集・11ha，湾央部東岸寄りの直径約200mで水深13mの礁池を取り囲むように存在・1群集・2ha，最も波あたりの強いリーフ上・4群集・4haであった．また，湾央部から湾奥部にかけては，水深約1.2m程度以下の非常に平坦な海底地形となっており，その領域では，ウミショウブが広く分布していた．

群体形状を区別しない全サンゴ被度分布は、おおまかに湾口部から湾央部で30%以上，湾央部から湾奥部にかけてのウミショウブ分布域で30%未満，湾の最奥部で0%であった．そこで，調査地点を，サンゴ被度が0%，1%-30%，30%以上の地点に分類し，物理環境（底面流速と土粒子数）との対応関係を見た．

底面流速は，季節によらず，卓状，短枝状，短細枝状，長枝状の順に大きく，またサンゴ被度30%以上，1-30%，0%の地点の順に大きく，特に冬季の底面流速は，被度30%以上の地点では，被度0%の地点の約2倍程度あることがわかった．また，土粒子数は，季節によらず，また粒径によらず，被度0%の地点で極端に多く，サンゴが生息する地点では，被度1%-30%の地点の方が30%以上の地点より多いことがわかった．

結果をまとめると，以下のようになる．1) サンゴ生育場所の底面流速が大きいほど，サンゴ被度が高い．また，群集タイプにより，底面流速が異なる．2) サンゴ生育場所の土粒子数が多いほど，サンゴ被度が低い．また，土粒子数が多い場所では，主としてウミショウブが生育している．

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キーワード：造礁サンゴ、流速、土粒子、西表島、崎山湾・網取湾自然環境保全地域
Keywords: reef building coral, wind speed, soil particle, Iriomote Island, Sakiyamawan-Amitoriwan nature conservation area

A dynamic model to assess mariculture-induced environmental impacts on seagrass beds along coasts of Bolinao and Anda, Philippines

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A dynamic model which reproduces the physical and biogeochemical environmental conditions and associated factors, can be an effective tool in determining coastal management strategies in an area influenced by intensive human activities. The outputs of the model suggest the need for proper assessment of the effectiveness of coastal management efforts which is made difficult by multiple environmental stressors such as pollutant discharge from rivers and from unregulated mariculture, the effects of which vary in space and time.

Seagrass beds are found in many coastal areas and their responses are regarded as key indicators of ecosystem health, are nursery grounds for fishes and invertebrates, and are major sources of primary production in coastal waters. However, their recent disappearance along many coastal areas in the world caused by anthropogenic stressors has become a serious global concern.

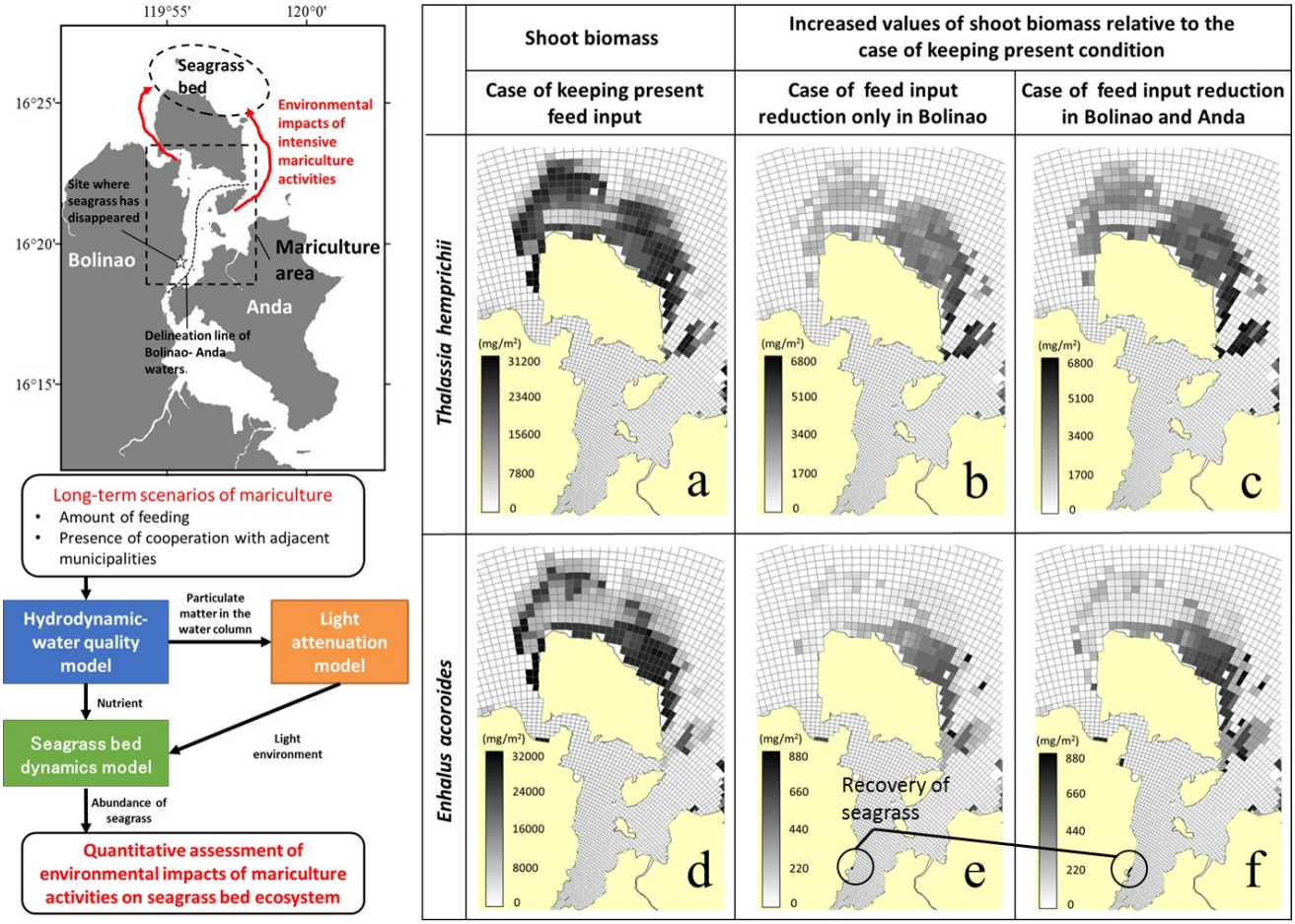
Our study site is located along the coastal towns of Bolinao and Anda in northwestern part of Luzon Island in the Philippines. Bolinao alone has at least 34 sq.km. seagrass area, an important resource for local communities as habitat of local fishes and invertebrates of economic value. However, the coastal waters of Bolinao and Anda are also a sites where mariculture has intensified. The area is known as one of the top producers of Chanos chanos (milkfish), an important food fish in the Philippines. The unregulated milkfish culture characterized by high feed input resulting in feed wastage, and proliferation of fish farm structures continue to degrade water quality in the area. Nutrient enrichment have resulted in excessive growth or blooms of phytoplankton and reduced light availability for the seagrass bed. Such environmental impacts due to excessive mariculture activities led to the decline and loss of seagrass species number and area at the site.

In order to assess the mariculture-induced environmental impacts on the seagrass bed ecosystem, a modeling system was developed to reproduce the spatial and temporal variation of water quality and associated light environment at the site, and evaluate the ecosystem responses to the environmental stressors. The modeling system is composed of a hydrodynamic-water quality model, a light attenuation model, and a seagrass bed dynamics model that computes seagrass growth using mass balance equation. This seagrass model was applied to *Thalassia hemprichii* (*Th*) and *Enhalus acoroides* (*Ea*), which are dominant seagrass species in the area. Results of the model indicate good agreement between observed and modeled values of seagrass biomass for *Th* and *Ea*, with coefficient of determination R^2=0.68 and 0.53, respectively.

To help implement proper mariculture regulation to conserve the seagrass ecosystem, the effectiveness of feed reduction was assessed by testing feed reduction scenarios for different combination of target areas. The results demonstrate that decreasing feed amount is an effective way to improve light conditions in the reef area. Results show that by reducing the feed amount in Bolinao alone, the biomass of both *Th* and *Ea* will increase (figure b, e), relative to the case of keeping present feed input amount (figure a, d), and there is recovery of seagrass in the mariculture site where seagrass has disappeared (figure e, area enclosed by

a circle). However, a remarkably greater increase in biomass and wider area of seagrass recoveries will happen if feed reduction is carried out by both Bolinao and Anda (figure c, f). These results clearly suggest the importance of mariculture management efforts through inter-municipality cooperation. The model can thus provide technical information that will be useful input to coastal management schemes for a sustainable coastal ecosystem.

Keywords: seagrass bed modeling, hydrodynamic-water quality model, eutrophication, mariculture, coastal management



沿岸生態系の経済評価：持続的な利用と保全の両立に向けて
Economic valuation of coastal ecosystem: balancing sustainable use and conservation

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Coastal ecosystem is one of the most valuable ecosystems on Earth; however, the ecosystem faces various threats from environmental changes due to anthropogenic activities and natural events including climate change. To conduct the sustainable management, the recognition of benefits from the ecosystem has become increasingly essential.
The objectives of this paper are to provide a review of the environmental valuation studies concerning coastal ecosystem and introduce some contributions of the economic analysis to sustainable coastal management and the associated policies. Furthermore, this paper illustrates two empirical environmental valuation studies of coastal ecosystem in Amami Islands, Japan. One addresses recreational values of the ecosystem; the other shows residents' preference for climate change adaptation in the coastal areas. The review and the findings of empirical studies point out that integrating economic values into decision-making is still challenging. Further work is required to establish integrated approaches considering local ecosystem management.

キーワード：沿岸生態系、環境評価、経済分析、生態系サービス、島嶼、持続的利用
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