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.

Keywords: mangroves, root function, soil chemicals

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.

Keywords: seagrass meadows, carbon storage, isotopic analyses, sediment, organic carbon

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.

Keywords: temerate zone corals, metabolic changes, cold temperature bleaching

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.

Keywords: coral bleaching, numerical simulation, zooxanthellae, reactive oxygen species

Minerals in Coastal Ocean: Recovery of Biomass-stocking Coral Reefs

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Atmospheric carbon dioxide-dissolving surface seawater dissolves minerals and biomass. Reversible chemical reaction mechanism of acid/base dissociation reaction is essential in growth of individual marine calcifying organisms and in development to their colony. Reversible calcification reaction, Ca^{2+} + HCO_3^- = $CaCO_3$ + H^+, was by accident discovered via acid/base titration measurements at 2007 year. In surface seawaters calcification/decalcification reaction corresponds to acid dissociation reaction as above mentioned but in fresh water it means precipitation/dissolution of physical reaction Ca^{2+} + CO_3^{2-} = $CaCO_3$.
The nature of surface seawater is controlled into weak bases as proton concentration homeostasis. Seawater acidification due to absorption of anthropogenic carbon dioxide from atmosphere leads to mineral dissolution. For a study on net calcification rate the pH-dependent evaluation of [Ca^{2+}] is essential by the standpoint of soluble carbonate chemistry. The sources of calcium ion concentration are expected from the leaching of minerals and biomass into coastal ocean or surface seawater. Biodiversity maintenance may be critical for coral reefs.
Key-word: Mineral, Coastal, Coral Reefs, Recovery Potential, Biomass

Keywords: Mineral, Coastal Ocean, Coral Reefs, Recovery Potential, Biomass

Genetic connectivity and speciation of reef-building coral

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Cora reef ecosystem is one of the most biologically diverged systems though coral reefs are now threatened by various stresses including local anthropogenic stress by coastal development, terrestrial discharge as well as global climate change. Corals in Japan are distributed near the edge of their distribution. For the last 80 years some coral species are reported to show range expansion toward north while some corals are severely degraded by coral bleaching due to high water temperature in tropical area (Yamano et al. 2011). Therefore, corals in Japanese waters is considered to be a very sensitive area to climate change and is facing dramatic change of coastal ecosystems. Under these circumstances, revealing genetic connectivity and assessing genetic diversity of coral reef organisms along Kuroshio Current provides important implications for mechanism of poleward migration and stability of temperate peripheral populations as compared with tropical “threatened” populations.
In this study, molecular genetic markers such as highly polymorphic microsatellite markers are used to estimate genetic structure of coral reef organisms. On estimating intra-species connectivity of reef-building coral species, hidden speciation if any, is simultaneously estimated by genetic clustering analysis.
Heliopora coerulea is a living fossil whose morphological characteristics has not been changed since ancient times (Cretaceous). *H. coerulea* fertilizes within female polyps and broods their larvae until they become almost competent for settlement. Clustering analysis using microsatellite markers as well as nuclear ITS2 marker revealed two hidden lineages along Kuroshio Current. Each of the lineage is sometimes distributed in the same region but intra-lineage gene flow among distant populations are stronger than inter-lineage gene flow in geographically close populations, indicating reproductive barrier between different lineages. One lineage (HC-A) prefers to distribute in colder area and often predominates outer reef slopes. The other (HC-B) prefer to distribute in warmer area and often found inside reefs. There is almost one month difference of reproductive timing of the two lineages. Northernmost habitat of HC-A is Yakushima while that of HC-B is Okinawa island. Even within the same lineage, gene flow of HC-A and HC-B is limited in accordance with low larval dispersal potential (pelagic larval duration is mostly within a few hours and up to two weeks).
In *Acropora hyacinthus*, possible three different lineages are found along Kuroshio Current. One of the three lineages can be found in both temperate and sub-tropical region while the other two lineages are found in sub-tropical regions, implying coral population in temperate region can act as a refugea at least for one of the three lineages. We found two of the lineages in Sekisei Lagoon. Genetic barrier analysis of the both lineages showed weak barriers among eastern, central and south western Sekisei Lagoon, suggesting these three region should be conserved separately as different management units. Recently appeared northernmost populations (Amakusa, Goto and Shikine) showed no sign of population bottleneck, suggesting these populations reproduce relatively stable since they were newly colonized. However lower genetic diversity (alleric richness) were found in these new populations suggesting more vulnerable to environmental change than other temperate populations. Especially, Goto population showed higher ratio of asexual reproduction and significant differentiation with other populations, local extinction of Goto population would require longer time for recovery.

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.

Keywords: anthropogenic nutrient, stable nitrogen isotope, Kenyan coral reefs, macroalgae

Relationship of coral distribution with bottom flow speed and soil particle quantity in Sakiyama Bay, Iriomote Island, Japan

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This study was conducted to clarify the relation between coral distributions and physical variables in Sakiyama Bay, Iriomote Island, Japan. First, distributions of coral coverage by the colony shapes and coral areas by the community types were investigated at 72 points around the bay. Next, results of numerical simulations for the physical variables such as oceanic flow and soil particle numbers under average sum-mer and winter conditions in the region were analyzed and compared with the obtained coral distribution.

The results are summarized as follows: 1) Coral coverages show a direct relation with bottom flows in the region, and the bottom flows differ with coral community types. 2) Coral coverages show an inverse relation with soil particle numbers in the region. Enhalus acroides mainly inhabit the region with a larger number of soil particles.

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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.

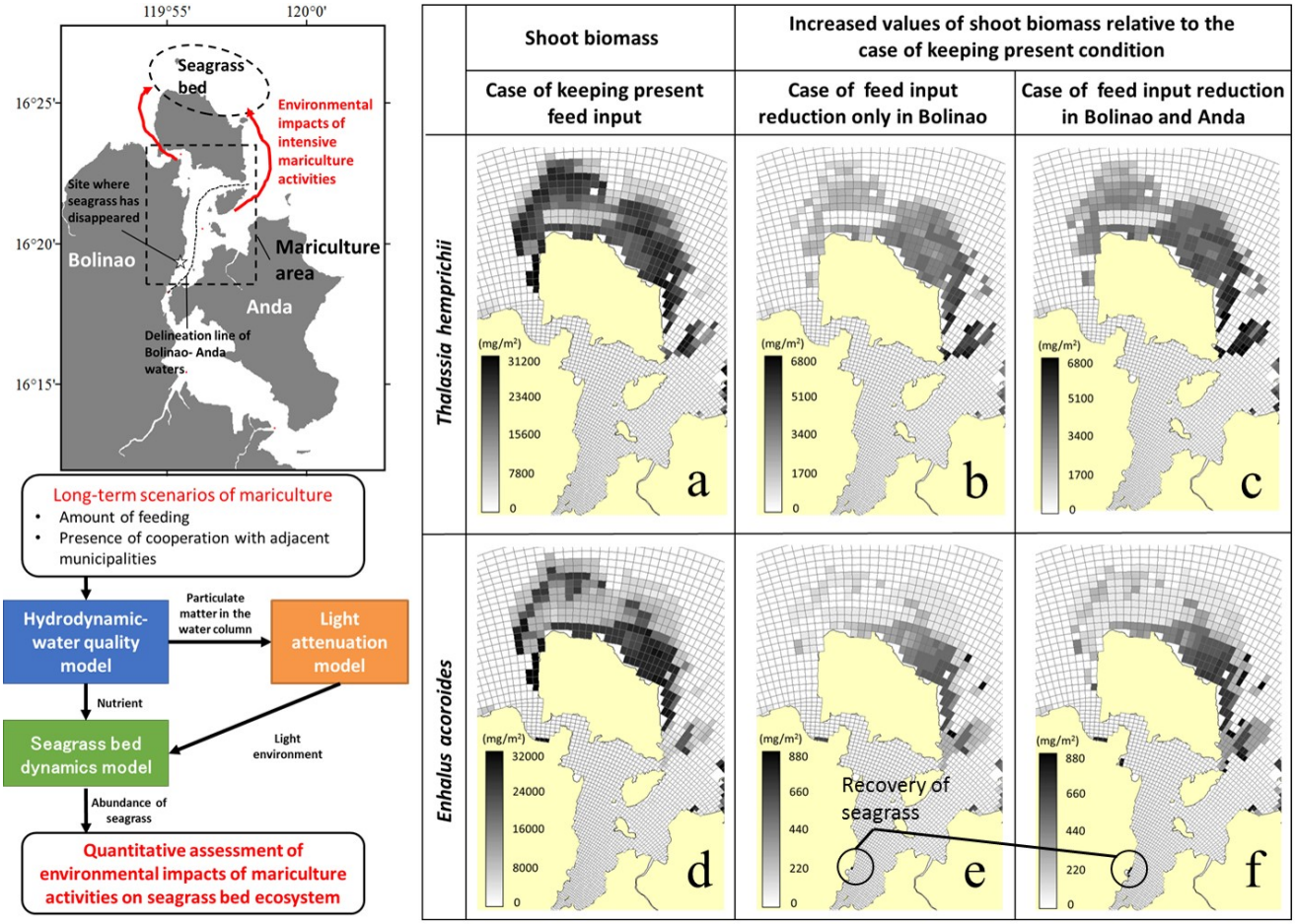
Our study site is located along the coastal towns of Bolinao and Anda in northwestern part of Luzon Island in the Philippines. Bolinao alone has at least 34 sq.km. seagrass area, an important resource for local communities as habitat of local fishes and invertebrates of economic value. However, the coastal 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



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.

Keywords: Coastal ecosystem, Environmental valuation, Economic analysis, Ecosystem service, Islands, Sustainable use

