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Islands ecological integrity evaluation using multi sources data

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ABSTRACT

The islands located adjacent to the mainland provide us a lot of natural resources supported by their specific ecosystem structure and function, but they are easy to suffer from anthropogenic pressures and environmental change impacts. The island ecological integrity evaluation is one of the useful tools for the island protection and management. In this study, we proposed the island ecological integrity concept and developed a multi spatial and temporal scale evaluation index system, including anthropogenic pressures, climate change impacts, ecosystem function, and ecosystem structure. We applied the method and used the multi sources data to evaluate the ecological integrity in Nanri island, Dongan island, and Chuanshi island in Fujian Province, China in 2006 respectively. The result showed that the I_{ACEE} scores were 0.61, 0.55 and 0.60 in Dongan, Chuanshi and Nanri islands respectively. The I_{AP}, I_{CC}, I_{EF} and I_{ES} scores were 0.72, 0.71, 0.43 and 0.54 in Dongan island; 0.71, 0.70, 0.40 and 0.39 in Chuanshi island; 0.67, 0.58, 0.41 and 0.62 in Nanri island respectively. The results indicated that the indexes system could reveal the islands ecological integrity on different spatial scales and spatial locations.

1. Introductions

Islands are very important nature resource pool because they cover diverse ecotypes, enriching the biodiversity on earth (Lagbas and Habito, 2016). They locate in the transitional zone with strong interaction in the ocean-terrestrial-atmosphere biosphere circle, the edge effect is obvious, the environmental gradient is large, the self-organization ability and self-recovery ability are weak (Wu et al., 1992). The islands near the mainland are important to human. They have economic, cultural, scientific, military and political values, which provide precious ecosystem services such as marine fishery production, primary production, wetland ecosystem gas regulation, ocean ecosystem waste disposal, and public education (Aretano et al., 2013). However, anthropogenic pressures and climate changes were easy to result in species invasion, habitat change, biodiversity lost in the islands (Garcia et al., 2017; Simaiakis et al., 2017). There is a need to quantitatively assess the environment influences on near the mainland islands.

Island ecosystem assessment has been applied to the islands' eco-environment protection and management. Qiu et al. (2007) assessed the ecological vulnerability of the western Hainan Island of China using a combined approach of landscape pattern and ecosystem sensitivity, and the evaluation framework included reciprocal of fractal dimension, isolation, fragmentation, sensitivity of land desertification, and sensitivity of soil erosion. Santos Gomez (2013) found adaptive trade-offs in length-weight allometry might reduce vulnerability under climate change of adult ground beetle assemblages in their original elevation stratum on Tenerife, which could assess the natural assemblages vulnerability and resilience. Gilman et al. (2014) evaluated the Marshall Islands longline tuna fishery ecological risks through a consideration of phylogenetic uniqueness, risk of population extirpation, risk of species extinction and importance in ecosystem regulation. Kurniawan et al. (2016) studied the level of vulnerability in small islands to tourism as a basis of integrated small islands management in Indonesian conservation area, and the vulnerability index included the coastline, coral reef, live coral reef, and development area. Shope et al. (2016) used near-surface wind fields from four atmosphere–ocean coupled global climate models (GCM) under representative concentration pathways (RCP) 4.5 and 8.5 to stimulate future wave climates of 25 tropical Pacific islands and found it will be necessary to assess island vulnerability under climate change in future studies.

Ecological integrity evaluation is one of the important means to resource management and environment protection, especially under the increasing influence of climate change and human activities. There were many ways by which we could understand the meaning of ecological integrity (Miller and Ehnes, 2000). One was ecosystem composition factors, which means an ecosystem reaches its optimum status at the specific geographic region. Thus, ecosystem would possess all the native biodiversity and ecological process that regional natural habitat

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should contain, the ecosystem structure and function not damaged by the human activities pressures, and the native species would reproduce sustainably (Karr, 1993; Woodley, 1993). Another was ecosystem characteristics, which included health, resistance, recover and self-organization ability (Andreasen et al., 2001). The self-organization inner process of the ecosystem also manifested that if an ecosystem could maintain its organization structure, stable status, resistance ability and recover ability, it is an integral ecosystem (Mller et al., 2000).

There were many concepts about ecological integrity. The similarities were ecological integrity includes structural integrity and functional integrity, and an integral ecosystem is self-sustaining, self-renewable (Karr, 1981; Castela et al., 2008). The differences were the consistency object they emphasis, such as the rate of ecosystem process, the selection of reference environment and the consideration of multi scales (Castela et al., 2008; Jiang et al., 2015; Rempel et al., 2016). For examples, Jiang et al. (2015) proposed an estuary wetland ecosystem has ecological integrity if its lands, waters, living beings and ecological structure and function are intact in different spaces and scales under pressure and can sustainably provide ecosystem service to humans. Rempel et al. (2016) proposed ecological integrity of managed forests includes the ability of an ecosystem to support a community of organisms with a similar species composition and functional organization as found in nearby natural systems.

To some extent, single disciplinary perspective has limitation in understanding ecological integrity. The large scale study mainly focus on the influence of climate factors on the ecosystem, which reflects the overall change of island macroscopically. While the small scale study mainly studies the individual behavior in the ecosystem, which shows the complexity and diversity within the island. If we use a single factor to evaluate the ecological integrity, the result is easy to influence by the personality of the factor. If we use a multi-perspective approach to evaluate the ecological integrity, the condition of the ecosystem could reflect objectively and comprehensively. Thus, we proposed the ecological integrity should comprehensively consider the multiple factors in study region, such as the spatial scale, spatial location, the physical, chemical and biological factors, as well as the interior condition and external influence of ecosystem.

The ecological integrity evaluation has been applied to many ecosystems e.g. river, wetland, estuary, coastal zone and forest by researchers. For examples, Broeck et al., (2015) reviewed the abiotic and biotic indicators that applied to the evaluation of freshwater habitats ecosystem integrity. In which, the abiotic indicators included nutrient concentrations, ion, PH, as well as chemical and biological oxygen demand. abiotic indicators included vertebrates, macroinvertebrates, zooplankton, macrophytes and phytoplankton. Chin et al. (2015) compared different methods for generating indices of biotic integrity for Great Lakes coastal wetlands using bird community data, and the methods included rank sum and multivariate approaches for defining landscape disturbance gradients, generalist-specialist, multimetric and probabilistic. Jiang et al. (2015) developed a multi-scale estuary ecological integrity evaluation index system including environmental quality, biology and ecology, landscape pattern and ecosystem management based on dissipation theory. Golfieri et al. (2016) choosed odonates as bioindicators for the ecological integrity of the river corridor, and developed the Odonate River Index based on the Odonate Habitat Index to assess the conditions of the whole corridor in alluvial rivers. Rempel et al. (2016) developed an ecological integrity indicator system based on simulated natural disturbance and indicator species to test the forest condition and habitat in managed forests, and the selected indicators included habitat function and forest condition.

In this study, we proposed the concepts of the near mainland islands ecological integrity, and built a multi scales island ecological integrity comprehensive evaluation index system that adapted to near mainland islands, including anthropogenic pressures, climate change impacts, ecosystem function, and ecosystem structure. We took the Dongan island, Chuanshi island and Nanri island in Fujian Province, China as examples and studied its ecological integrity in 2006 using a comprehensive evaluation method, with the support of field measurements data and multi sources remote sensing data. The study provided a theoretical basis for the island protection and management.

2. Methods

2.1. Comprehensive evaluation index system

2.1.1. Islands ecological integrity concepts

The island ecological integrity should consider the space location and scale heterogeneity in island ecosystem. For space location,

Table 1
Island ecological integrity evaluation framework.

Hierarchy 1	Hierarchy 2	Hierarchy 3	Hierarchy 4
A1 Ecological integrity	B1 Anthropogenic pressures	C1 Marine environmental quality	D1 Inorganic nitrogen (DIN)
			D2 Inorganic phosphorus (DIP)
			D3 Chemical Oxygen Demand (COD)
			D4 Petroleum
			D5 Eutrophication status index
		C2 Sediment quality	D6 Sulfide
			D7 Organic carbon
			D8 Petroleum (sediment)
		C3 Land use status	D9 Land use degree index
			D10 Landscape fragmentation index
	B2 Climate change impacts	C4 Precipitation	D11 Mean annual precipitation
			D12 Mean annual precipitation change velocity
		C5 Temperature	D13 Mean annual temperature
			D14 Mean annual temperature change velocity
		C6 Natural disasters	D15 Red tide frequency
			D16 Typhoon frequency
	B3 Ecosystem functions	C7 Ecosystem resistance stability	D17 Landscape diversity index
		C8 Ecosystem recover ability	D18 Ecological elasticity index
		C9 Self-organization	D19 Energy capture
			D20 Exergy dissipation
		C10 Ecosystem vitality	D21 Net Primary Productivity (NPP)/Gross Primary Productivity (GPP)
	B4 Ecosystem structures	C11 Phytoplankton	D22 Diversity index
		C12 Zooplankton	D23 Diversity index
		C13 Intertidal benthos	D24 Diversity index
		C14 Shallow sea benthos	D25 Diversity index
		C15 Terrain	D26 Average land slope