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Sustainable Utilization of Resources and Environmental Management in Coastal Areas of the Harima Sea (Eastern Area of the Seto Inland Sea)

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The use of coastal regions is expected to become diversified and multiple uses in the future, as reflected in the recent rising interest in waterfront areas. In order to promote a more sustainable form of resource utilization, the coordination with environmental conservation issues among various users is essential to future waterfront development.

To help draft proper policies for overall coordination among and management of these different requirements, this paper reports the development of an empirical model, based on a case study of the Harima Sea coastal area (eastern area of the Seto Inland Sea), which explores ways to achieve sustainable utilization and optimum environmental conservation of coastal area resources.

1. Introduction

In Japan, an island country surrounded by the sea, it is expected that an integrated and multiple utilization of coastal areas, where combined use of land and sea is possible, will be increasingly required in order to meet the demands of increasing population for urbanization and economic development. Inevitably, the increased and concentrated use of coastal areas will lead to various conflicts, such as destruction of the coastal environment and ecosystem, competition with more traditional users of the coastal resources for fishing, marine transportation and so on.

Based on the concept that coastal areas should be considered public resources, and that a system should be established to coordnate the sustainable maintenance and the optimum use of these invaluable resources, this paper presents an empirical model which permits the following conditions:

(1) The values of economy, environment and resources should be evaluated in some aggregated way.

(2) The locational allocation and distribution of economic and environmental assets among economic actors shall be analyzed

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throughout the whole region.

(3) Future allocation and distribution will also be predicted, providing a proper measure for resource allocation to present and future generations.

2. Economic-Ecological Model

Ikeda(1987) introduced a theoretical economic-ecological model (E-E model) which reflects the mutually dependent relationship between economic activity in the coastal land and the associated marine ecosystem, and proposed an empirical approach to link an input-output model of economic system and a model of the marine ecosystem with environmental and resource factors. To achieve condition (1), this model combines the economic model of the coastal land area with the ecosystem model of the coastal sea area so that economic, environmental, and resource indices can be evaluated in a comprehensive manner.

For condition (2), an input-output model is used as an economic model in order to evaluate benefits received by the economic sector (industries) as well as to evaluate environmental pollution and the consumption of resources which accompany such benefits. In the simulation model of the marine ecosystem, the sea area is divided into a 40×25 mesh grid 2.5 km-wide horizontally and into three layers vertically so as to obtain the spatial distribution of red tide occurrences, especially during the summer. For condition (3), this simulation model is used to estimate the future state of resource utilization, through the comparison between the present situation and future situation of resource allocation to present and future generations.

Policy evaluation will be carried out by repeated communication between scenario writing with respect to alternative policies and the results of computer simulation.

3. Modeling Approach

The E-E model consists of,

1) the economic input-output table of the coastal land area,

2) the table of the resource utilization unit of the economic sector in the coastal area,

3) the table of the loading unit of water-polluting generated from the coastal land area, and

4) the marine ecosystem simulation model (see Figure 1).

The following is brief description for these tables and models.

(1) Economic input-output table in the coastal land area

For a region such as the Harima Sea coastal land area, the construction of an economic input-output table is considered to be extremely difficult due to limited data and the high degree of openness associated with the local economy. Therefore, a relatively simple method has been adopted, in which an input-output table is prepared by estimating a self-sufficiency rate for the specific region from the prefectural input-output table that has been regularly established by the prefectural government since 1975. (Sakashita, 1983).

The standard regional economic input-output model formula is as follows:

$$X = (I - \hat{R}A)^{-1}(\hat{R}F + E)$$

X: Output column vector of the economic sectors
$\hat{R}$: Self-sufficiency rate diagonal matrix
A: Input coefficient matrix
F: Column vector of final demand in the region
E: Export (out of region) column vector

The prefectural data are applied in $\hat{R}$ and A of the concerned region; F and E of the concerned region are estimated from the prefectural data, using the population or employment population; X of the region is determined under the following condition:

$$N = \hat{L}X,$$

N: Employment population in economic sectors
$\hat{L}$: Employment coefficient diagonal matrix estimated from prefectural data

(2) Table of the resource utilization unit of the economic sector in the coastal area

While modes of resource usage and types of resources that each economic sector requires usually vary, the primary unit table is prepared for data on fishing (boat fishing, fishing farming), recreation (bathing, shellfish gathering), marine transportation, and industry (including ports and harbors) as modes of resource usage, such as the coastlines, shoal and sea water area as well as sea bottom area.

(3) Table of the unit of pollution loading generated from economic sectors

Water-polluting substances are produced from household and industry and also from natural origins. In terms of COD emission load, 53% came from household sources and 36% from industrial sources (1984). For this reason, in addition to the loading unit from industrial activities, the loading unit of the household based on population data has also been established. The table of the pollution loading unit covers chemical oxygen demand (COD), total phosphorus (T-P), and total nitrogen (T-N), which are all closely related to the occurrence of red tides.

(4) A simulation model of the coastal ecosystem

Ikeda and others (1986) developed a simulation model of the coastal ecosystem of the Harima Sea (see Figure 2). Assuming that the occurrence of red tides is a result of eutrophication in the coastal area, this model shows the dynamic state of red tides in terms of the material circulation of basic nutrients and planktons. The nutrients (Nitrogen = N, Phosphorus = P) and the photosynthesis of phytoplankton (Flagellar algae = PH1, Diatomaceous algae PH2) are the basic production force in the coastal waters. The elements of the ecosystem in the food chain include the primary consumer (Zooplankton = Z) and the secondary consumer (Fish = F) and organic suspended substances (Detritus = D). This model is used to examine, through numerical data experiments, how the dynamic state of the marine ecosystem in coastal area is influenced by inflow of total phosphorus and total nitrogen, the volume of which is estimated from the calculated input-output model and the loading units of household and industrial activities.

4. Simulation Results from Several Policy Scenarios

First, the actual states of economic and resource utilization in 1985 are estimated, and the simulation is extended up to the year 2000. In this simulation, the real economic growth rate of Hyogo Prefecture is set at 3 - 4%. As for alternative policy options, sewage system development is taken as a measure of environmental policy. The impact of this policy measure is gauged by manipulating the sewage treatment coverage rate as an external policy variable. Regarding the resource allocation policy, full environmental protection (e.g. land filling of natural beaches and shoal area should not be permitted) and the opposite policy of free land filling are also examined.

The following are the major observations;

(1) The source of water-pollution load is heavily concentrated in particular industrial sectors in terms of volume and composition. (The pollutant load from the iron and steel industry will decrease due to the structural change in the regional economy, while the level of pollutant load from retail industry will drastically rise.)

(2) Export activities largely (70 - 80%) contribute to the pollution load in all pollutants. For total phosphorus, the ratio of contribution by the commerce activities is relatively large (30%).

(3) At the present time (1985), there is a shortage in absolute quantity of sandy beaches which are needed for bathing and other recreational

activities. Given the resource unit of necessary shorelines that was estimated by tolerating the present state of congestion, it would be difficult to secure the sandy beaches needed for bathing demanded by the year 2000 without adopting a more environmentally protective policy.

(4) The predicted rate of resource use in terms of the shoal area in the year 2000 does not show much change from present levels, when economic growth is set at 3% (95% at present, 97% in 2000); however, at 4% of the economic growth, the rate of resource use jumps to 120% because of the expansion of marine transportation and land fill to meet increased industrial demand for the shoal area including ports and harbors.

(5) The predicted pollution load in the year of 2000 approaches the worst level of 1979 with a 3% economic growth rate, and becomes even worse with a 4% growth rate. In the simulated result of the marine ecosystem, if sewage treatment coverage dose not improve, greater damage to fish farming is expected due to the increase in diatomaceous phytoplankton (see Figure 3).

As for chattonella phytoplanktons (red tide organisms), even higher sewage treatment coverage (90% in Hyogo Prefecture in 2000) cannot achieve improvement sufficient to decrease the red tides, due to the high concentration of nutrients in the lower layer of the sea area.

5. Concluding Remarks to the Development of Economic-Ecological Model

Further improvement is still necessary for each of the E-E modeling approaches, for example, more precise construction of the regional input-output model, and the construction of decision-support models applicable to resort-oriented and recreational development in the coastal areas, which is expected to grow in the future. Nevertheless, the E-E model is useful in allowing the overall evaluation of economic activity, the environment and ecosystem of the coastal areas where sophisticated and multiple use is expected in the future. It is also believed that our approach, which is implemented in dialog style with a computer, provides a useful tool to decision-makers.

It should be noted that a more elaborate E-E model is expected to be constructed in the future by integrating environmental economics and system ecology research results into the sustainable development model in the coastal area, so that the E-E model can work as a valuable means of comprehensive regional planning.

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POM were observed in the W of Buenavista Bay (20-35%) and in Perros Bay (30-68%). In the former, hurricanes "Flora" (1963) and "Kate" (1985) produced total and partial closures of some channels that existed before in the westward bank of Guani, and a strong land sediment runoff. In the W of Perros Bay, the highway that traverses it from N to S since 1988, may have enhanced POM accumulation (68%), mainly in the West side.

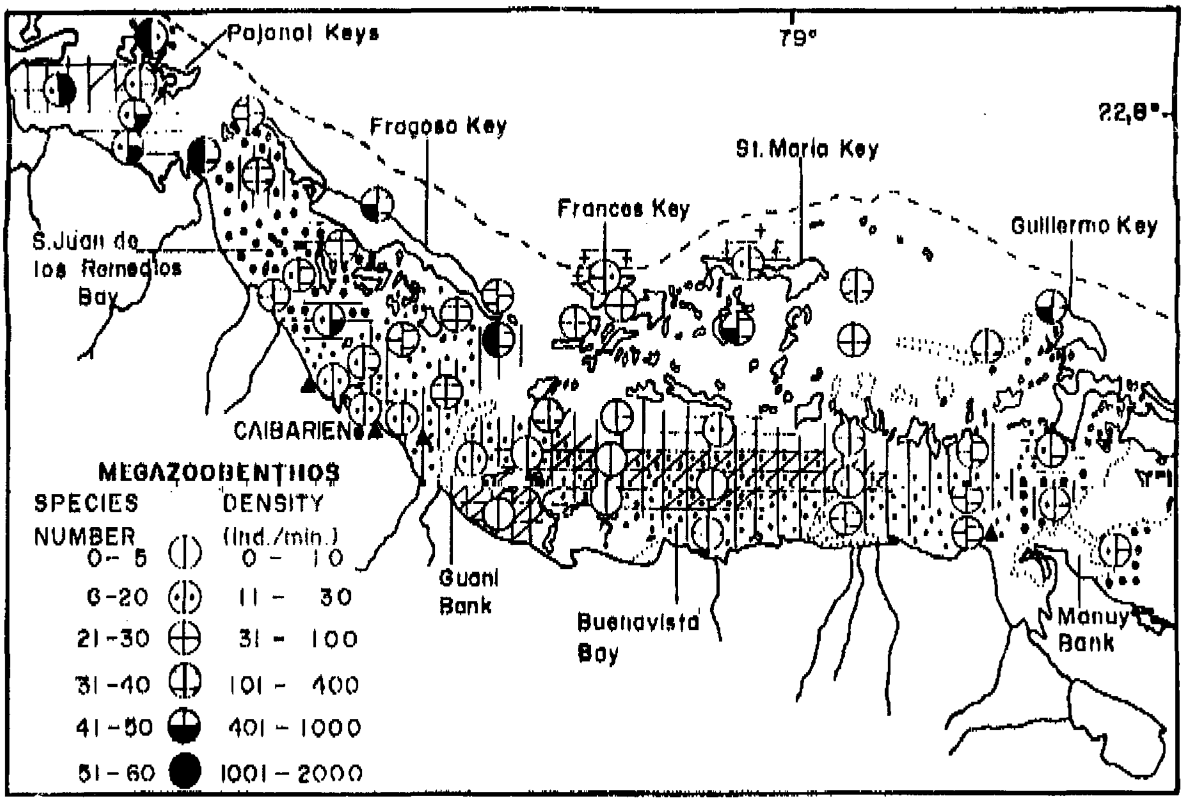

Fig.1 Number of species and density index (individual per minute of trawling) of megazoobenthos, and environmental stresses in an example section of the whole study area San Juan de los Remedios and Buenavista bays). Thick mud layer and water turbidity (vertical lines); absence or poornessof macrophylobenthos (horizontal lines); POM over 25% (loping lines); salinity maxims of 41-47% (tiny dots);salinity maxims higher than 47% (thick dots); high turbulance (+); and pollution (black triangles).

In great extensions of the macrolagoon, the bottom is covered with a layer of mud of variable thickness (Fig. 1). For that reason, waters are predominantly turbid because of mud suspension produced by waves in such very shallow areas (rarely more than 3 m depth).

In the western part of the Bay of Bvenavista, high rates of microbial activity were measured; The bottom is virtually void of megazoobenthos; and there is a strong odor of sulphidric acid in the sediments.

Absence and scarcity of macrophytobenthos are widely spread in the archipelago (Fig. 1). This is due mainly to the high water turbidity produced by sediment suspension, that interferes with light penetration down to the bottom, even in very shallow areas. Sediment deposition on leaves and fronds, creates a light - interfering film which also diminishes photosynthesis. Macrophytobenthos biomass increases accordingly toward the shallower bottoms of mainland and keys coasts, and submerged banks, even where turbidity and sedimentation persist. The commonly dominant macrophytes are the phanerogam Thalassia testudinum and several species of the genus Halimeda. Other seagrasses and algae predominate in more restricted areas.

Species richness (number of species) of megazoobanthos is an adequate indicator of global environmental favourableness. The number of species in the archipelago is constrained by a series of stressors that operate in isolation or in different sets of combinations; high and fluctuating salinities; great POM content in the sediment; presence of a mud layer on the bottom; water turbidity; sedimentation; water turbulence; absence or scarcity of macrophytobenthos, and pollution.

Low numbers of species are widespread in the archipelago (Fig. 1). The highest numbers of species were found in areas with rather great water exchange with the oceans, coupled with the presence of seagrass beds. In such conditions, salinity rarely or never reaches high values (36-41%); sediments are comparatively stable; and there is no intense accumulation of POM (5-15%) and mud (Fig. 1,2). Macrophytes supply food, substrata and shelter to many benthic species that otherwise would be absent.

The population density (individuals/minute of trawling) of megazoobenthos depends not only upon the above mentioned factors, but also upon biotic exogenous conditions, such as food availability and predation pressure, as well as biological endogenous properties (i.e. bionomical strategy). Thus, in stressed environments, relatively high benthic densities may be found, due to the dominance of a certain type of species.

Consequently, it can be expected that density, and species richness distribution patterns, do not match completely (Fig. 1)

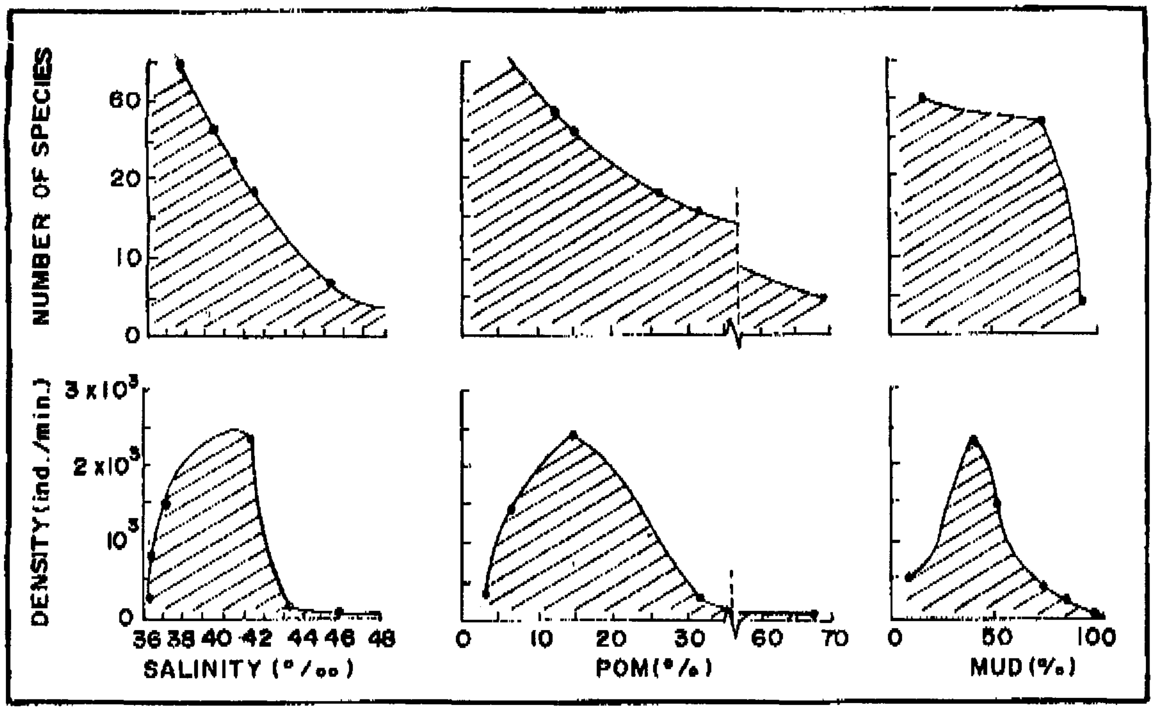

Fig.2. Area of variation in number of species and density of Megazoobenthos in relation to salinity, POM and mud content.

Highest megazoobenthic densities were paired with the following conditions: salinities of 37.5 - 41.5%; POM content in the sediment between 5-15%; absence of a thick muddy layer on the bottom; abundance of macrophytobenthos; low infered wave energy and sedimentation rates.

It was interesting to observe that, provided all of the above mentioned factors are within tolerable ranges, another factor (that we call, "retention or pocket effect"), favours an additional increase in megazoobenthic density. This factor is the location of the community in a place, westward to which, there in a "pocket" of land or keys that allows retention of advecting bioparticles (food and larvas of benthic colonizers) from the eastern water bodies. These conditions are found in the W part of Santa Clara Bay; W part of Port Sagua la Grande; SW part of Pajonal keys (Fig. 1); and W part of Mayanabo Cove.

A cartographic distribution of inferred stress levels was elaborated, where, in addition, specific environmental constraints in most stressed stations were pointed out. For ranking stress levels at each station, species richness was taken into account, and in stations where the number of species was low, population density was also considered.

As most stressors are directly or indirectly linked to the water circulation regime, recommendations to highways projects are being given with the aim of securing maximum possible conservation of natural water fluxes between inner water bodies, and full exchange rates with the ocean. In that way, the vulnerability of the areas involved, and the need for conciliating local ecological requirements with economical factors, are considered.

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