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Development of ecological indicators for the Dutch section of the North Sea

Saa H. Kabuta and Elizabeth M. Hartgers

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Sustainable use of marine waters has a high priority as part of international and national agendas. The quality of marine ecosystems reflects both the level of human pressures and natural environmental processes. Knowledge is key to making efficient policy recommendations regarding ecosystem management. In the past decade, the development of indicators has played an important role in enabling policy-makers to understand ecosystem changes while helping them make concrete recommendations towards improvement of their marine environments. Such indicators should describe the quality of the ecosystem, have strong scientific basis, and have the advantage of simplicity. This article presents the steps taken to develop ecological indicators for The Netherlands section of the North Sea. Among the current set of indicators used in The Netherlands, two are presented to illustrate how they are used in ecosystem management.

Keywords: ecological indicator, ecosystem approach, ecosystem management, GONZ, SOVON.

S. H. Kabuta: National Institute for Coastal and Marine Management (RIKZ), PO Box 20907, 2500 EX The Hague, The Netherlands [tel:+31 70 311 4324; fax: +31 70 311 4321; e-mail: s.h.kabuta@rikz.rws.minvenw.nl]. E. M. Hartgers: Regional Directorate for Water Management, North Holland, PO Box 3119, 2001 DC Haarlem, The Netherlands [tel: +31 23 530 1301; fax: +31 23 530 1302; e-mail: hartgers@DNH.rws.minvenw.nl]. Correspondence to S. H. Kabuta.

Introduction

The Netherlands has implemented various projects to improve the level of knowledge of the ecosystem of The Netherlands section of the North Sea (Kabuta and Duijts, 2000). The GONZ project (GONZ is the Dutch acronym for indicator development for the North Sea) was designed to use monitoring data in the development of ecological indicators to evaluate the level of human impact on the quality of the ecosystem. Ecological indicators are used to measure ecosystem integrity and may incorporate multi-dimensional information. Those developed in the GONZ project are based on biological components of the ecosystem including information on species, groups of species, and communities. Associated with these components are various organizational levels and functional elements of the ecosystem that include productivity, predation, and reproduction.

The development of indicators in the GONZ project started by integrating the relevant ecological components of the National policies for Water Management and Nature Conservation in The Netherlands (Duel *et al.*, 1997). Two main policy themes were selected: the conservation of biodiversity and the sustainable use of the ecosystem. Ecosystem indicators were identified for each of these two themes (Table 1). Biodiversity covers diversity of species, community, and habitat, while sustainability is linked to various uses of the ecosystem (e.g. fishing, shipping, sand extraction) as well as ecological processes (e.g. production and predation among ecological groups). The indicators were selected based on the following criteria:

- representative of a functional response of the ecosystem
- easy and inexpensive to monitor or be based on modelling results
- relevant to existing policy recommendations
- sensitive to the changes in the ecosystem
- sensitive to specific human activities
- availability of long-term time-series.

The final list of indicators was screened by a committee of scientists, policy-makers, stakeholders and managers (Duel *et al.*, 1997). Information about changes in the ecosystem were obtained using long-term data on the indicators (Kabuta and

Table 1. The current set of ecosystem indicators.

Parameters/ecological groups	Zoo and phytoplankton	Macrozoobenthos	Marine fishes	Sea mammals	Coast and sea birds
Species diversity	No. of species (SW)	No. of species (SW)	No. of species (SW)		
Population density		Density / m^2	Density per species	No. / km^2	Breeding population
Community structure	Ratio flagellates/ diatoms	r/k strategy	Length / weight per species		
Primary production	Production level C gr cm^2 / year				
Secondary production (grazers)	Copepod density	Biomass benthos g / m^2			
Tertiary (somatic) production			Biomass commercial landings per species	Individual biomass	
Food web					
Top predator density			Population size and distribution	Population size and distribution	Population size and distribution
Size of food storage		Prey organism spisula (m^2)	Prey organism (herring)		
Trophic structure		Types of feeders (IT index)			Types of feeders

SW = Shannon-Wiener index; empty boxes indicate no ecosystem indicator yet selected.

Duijts, 2000). In the remainder of the article we discuss two ecosystem indicators.

Example 1. Changes in breeding populations of the sandwich tern *(Sterna sandvicensis)* as an indicator for coastal and marine habitat conservation. – Policy recommendations for habitat conservation in The Netherlands stress the need for nature conservation regions in both marine and coastal areas. The increase in breeding populations of birds in these areas form one of the elements for assessing the success of this policy.

The sandwich tern is a coastal seabird often found foraging (up to depths of 20 m) in the Dutch Coastal Zone and estuaries (Delta and Wadden Sea) (Stone *et al.*, 1995). Their food comprises mainly small fish such as sprat, young herring, and sandeel. The breeding population is affected by water quality and the accessibility of food. The tern lives in large groups on the beach during the breeding season and at sea when not breeding. At all times of the year, the tern shows a high sensitivity to various forms of human influences, including recreational activities, toxic substances, and fisheries. The size of the population is strongly associated with the richness and availability of nesting grounds (Stone *et al.*, 1995).

Data on sandwich tern populations are collected primarily through an annual monitoring programme conducted by the National Institute for Coastal and Marine Management (RIKZ). Additional data are collected by various voluntary study groups specializing in nature conservation in The Netherlands. The data on breeding birds are managed by SOVON. The breeding success of the sandwich tern is determined annually in a number of colonies in the Delta estuary and in the Wadden Sea.

Following a minimum in 1991, the number of breeding pairs of sandwich terns in the Delta increased (Figure 1). This trend is directly related to management policies. In 1991, high intensity of recreational activities in the Delta area disrupted the breeding population of terns, causing them to migrate in huge numbers to the nearby coast of Zeebrugge, Belgium (Meininger *et al.*, 1999). As a direct result of policies to severely limit human encroachment on the breeding birds, there was a major decrease in recreational activity in 1993 and a large number of the breeding sandwich terns returned to the Delta region.

Example 2. Changes in the structure of macrozoobenthos infaunal communities in the North Sea as an indicator of disturbances on the seabed. – Fishing and sand extraction in the North Sea affect benthos fauna communities in various ways. These communities are often removed from their habitats, buried under organic matter, or killed directly. Demersal fisheries activities are also considered

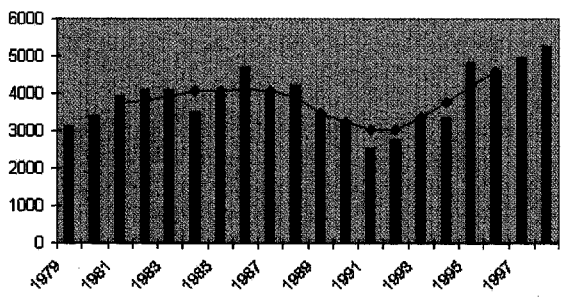

Figure 1. Changes in the breeding population of the sandwich tern.

responsible for major changes in both the functional and the organizational structures of the local benthos communities.

From the point of view of sustainability in The Netherlands North Sea, management actions are being directed towards reducing the negative effects of human activities, such as fisheries, on the ecosystem. Monitoring data have long been used to calculate diversity indices as a measure of the quality of the benthos communities. These indices, in principle, describe the level of species richness in the various parts of the Dutch section of the North Sea (Holtmann, 1997). Besides these diversity indices, few other indices are used to describe the impact of human activities on benthos communities in the North Sea. One exception is the Infaunal Trophic (IT) index (Word, 1979).

Word (1979) characterized the coastal waters of South California using the IT index, which selects a number of species within a given area based on their frequency of occurrence and dominance (>40%) in the samples collected during monitoring. Omnivorous, predatory, and herbivorous species are excluded. The selected species are divided on the basis of their feeding strategies. Group 1 consists of organisms that feed by capturing suspended particles drifting into their mucous traps or filter systems. These "suspension feeders" tend to dominate areas where sediment levels of BOD are relatively low. Group 2 comprises "interface feeders" with most of the male organisms feeding on suspended particulate matter while the females feed on surface detritus. Group 3 species feed on detritus on the seabed and are called "surface deposit feeders". They dominate where BOD levels are slightly increased due to anthropogenic activities. Group 4 feed on detritus found under the surface of the seabed. Significant amounts of mud pass through the guts of these "subsurface feeders". The values of the IT index for Groups 1 through 4 are between 100 and 75, 74 and 49, 48 and 25, and 24 and 0, respectively.

The IT index is measured by using the selected number of species belonging to each of the four groups. The index is calculated by using the formula:

$$\text{IT index} = 100 - (100 \times (0n_1 + 1n_2 + 2n_3 + 3n_4))/3n_1 + n_2 + n_3 + n_4$$

where n_1, n_2, n_3, and n_4 are the numbers of individuals in Groups 1, 2, 3, and 4, respectively. The value of the IT index lies between 0 and 100. The closer the number is to 100, the less disturbed the seabed, and suspension feeders dominate. When the index is closer to 0, the seabed is relatively highly disturbed and subsurface feeders dominate.

The IT indices for The Netherlands section of the North Sea between 1991 and 1998 show the highest index, indicative of less seabed disturbance, to the north of the oyster grounds (Figure 2). In the offshore regions of the North Sea, lower indices were observed, although they were slightly higher in 1994 and 1995, indicating less seabed disturbances in those years. The indices in the coastal region lie between 30 and 60, indicative of continuous disturbance during the study period.

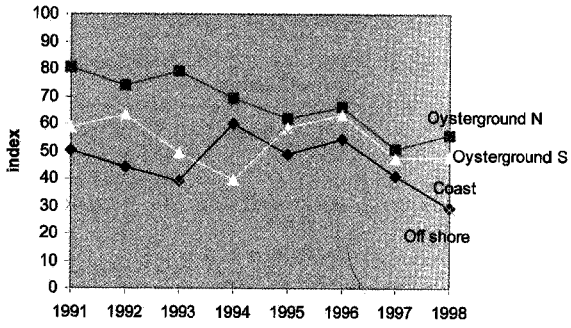

Figure 2. The time-series of the Infaunal Trophic (IT) index for four regions of The Netherlands section of the North Sea.

Conclusions

A suite of indicators is presently being used to evaluate nature policy objectives for The Netherlands section of the North Sea. The techniques learned within the GONZ project have served as input to the development of ecological quality objectives (ECOQO) for the North Sea. The development of ecological indicators is far from complete. Future work includes the development of scientifically sound and politically acceptable reference values for the indicators. Further efforts should be geared towards integrating different sets of indicators (socio-economics, governance, physical and morphological) and to link the indicators with specific human activities.

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