"Health Examination" – a semi-enclosed coastal environment: a new concept for marine environmental monitoring

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Abstract

The problem in water quality has become obvious in the coastal waters of Japan since about 1970. Some areas developed an unpleasant odour and a lot of fish died in many areas where industrial activity was flourishing. The monitoring of these areas started together with missions designed to deal with this water pollution. As a result, the water quality recovered to a constant or decreased level but fishery resources have not recovered to a level to support the Japanese demand for consumption. Was there a problem in the ideal way of restriction and monitor that focused on the water quality? We propose a "Health Examination of the sea" as a new oceanic environmental diagnosis to monitor and evaluate water quality. This diagnosis focuses on biological production and the purification ability of the sea. The "Health Examination of the sea" method covers ecosystem stability and smoothness of material cycling. This method was devised to understand at an early stage trends in environmental deterioration by using a standard which focuses on the range of variation in the environment parameter of each area, and not a standard that uses an absolute value. In effect, this new evaluation method incorporates the concept of preventive medicine. Our objective is to clarify the points of difference between the established monitoring method to redress water pollution, and to introduce a new approach to marine environment protection.
Keywords: Health Examination, monitoring, ecosystem, materials cycle, enclosed bay.

1 Introduction

The sea provides us with numerous benefits including aquatic resources through its diversified food web systems. However, its vulnerability to such damages as over-nutrition resulting from land-based human activities has lately claimed increasing attention. A marine ecosystem has its own specific mechanism, comparable to that of a human body, for maintaining a material balance. Rivers carry nutrients down into, for example, a semi-enclosed bay estuary to be dispersed, where food webs work for biological production, decomposition and purification. In a sense, fishing also helps maintain the balance by preventing overpopulation of organisms.

In recent years, the disappearance of ecologically important shallow water areas along the coast, including tidal flats and seagrass beds, has brought a decrease of biological water purification ability through a food web (Suzuki et al. [1]. With a limited water exchange with the open sea, semi-enclosed bay estuaries, in particular, suffer from serious impacts resulting from the reduction of shallow water areas.

In this context, the authors are proposing the establishment of guidelines to carry out a "Health Examination (diagnosis) " for the estuary, that is marine environmental monitoring that aims at more precise diagnosis of an estuary's condition. This paper outlines the guidelines: check sheets to know ecological features of semi-enclosed bay estuaries; primary monitoring similar to a daily checkup using available data and environmental information obtainable by easy measurement, and advanced monitoring comparable to a thorough physical examination based on specialized measurements and analyses to examine the "health of the sea" and identify the causes of damage suffered.

The authors have employed two criteria for examining the health of the sea. Two criteria are "Stability of an ecosystem" and "Smoothness of a materials cycle". Accordingly, it is essential in this research to properly monitor not only data on the standing stock of a material at a certain point of time, but also its flux and flow. This article presents the monitoring items selected in accordance with the above-mentioned criteria using some case study results. The necessity of organized efforts toward continuous monitoring and the management of that data are also discussed.

2 Definition of a healthy sea

The sea provides us with numerous benefits through its existence and its functions. It is essential that we take care of the health of the sea so that we are able to continue enjoying those benefits.

While many of these benefits–ranging from adjustment mechanisms to climate change, through the function of preservation and accumulation of matter, and the function in the marine transportation and amenities–exist, this paper focuses on the role it performs in nature in the biological production.

While the materials being carried from land is diluted and dispersed throughout the sea, the sea itself is a field of biological production that contribute to the formation and growth of food webs and species regeneration which eventually return to human beings as a food source through the materials cycle that supports biotic production. The sea is healthy when this production function is being maintained in a healthy condition, and the ecosystem and materials cycle bearing the food chain are essential to maintaining this healthy condition.

For an ecosystem to sustain biotic production it must be rich in both quantity and diversity of species. In addition, it must be capable of restoring itself to maintain the continuity of the food chain even when species are transformed due to natural causes or there is a temporary distortion due to external causes. For the materials cycle, what is of vital importance is that continuity is maintained through both space and time so that the cycle continues without interruption. Accordingly, a healthy sea is a sea where the stability of the ecosystem (i.e. its restorative capacity) is great and the materials cycle is functioning smoothly. For this reason, our Sea Health Examination focuses on the ecosystem and the materials cycle.

3 Items in the Health Examination

The basic structure of the ecosystem and materials cycle in an estuary is shown in Fig. 1.

In coastal areas, nutrients input from land are caught in the shallow water zone, typically sea grass beds and tidal flats, where organic matter purification and production take place. In seawater, biological resources are produced through primary production brought about by photosynthesis, and then through a food web organic matter is transported to upper trophic level. The organisms in each trophic level are often removed from the system by birds or fishing activities. Organic matters entering the bottom layer are eaten by benthic organisms strongly fixed to the bottom and decomposed by micro-organisms such as bacteria to eventually be regenerated into the seawater. This process consumes oxygen. Apart from this internal cycle, advection and dispersal to the open sea also occurs as a result of physical processes such as tidal current and density current.

The groups of organisms from the lower to the higher trophic levels in this structure form an entire food web, beginning from primary production and the entire system, including the seagrass beds and tidal flats which provide the habitats to organisms, is the ecosystem referred to in this paper. The materials cycle through loading, production, sedimentation, decomposition and diffusion show the flux (flow) of the materials. The deciding factor in the stability of ecosystems is the condition of marine organisms, which all together are the major components of the ecosystem. While it is not at all feasible to try to examine the condition of all marine species, it is possible to examine the very base for the existence of the organisms. We have chosen three factors as items for Sea Health Examination: biotic composition, habitat and environment for habitat.

For "smoothness of the materials cycle", we have selected five items typifying material flow to be examined: the load, represented by materials going into the sea water; water exchange between an estuary and open sea; primary production, which is the production of organic materials and oxygen through solar energy; decomposition and sedimentation, the consumption of oxygen and the accumulation of organic materials; and removal, which is the removal of marine material from the ecosystem.

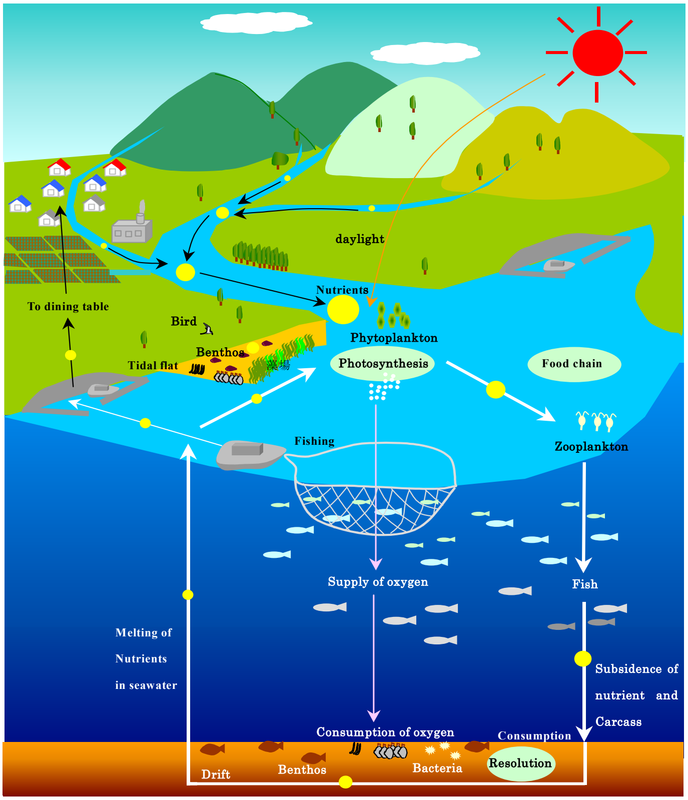


Figure 1: The basic structure of the ecosystem and materials cycle in enclosed seas.

4 The structure and process of the Sea Health Examination

The Sea Health Examination enables us to examine the health condition of a sea continuously and accurately, and it can be used to control conditions and take preventive action to maintain sea health. Not only that, when any sign of deterioration is detected, the Health Examination should be able to help us accurately identify the causes and find ways to overcome them and restore the health (environment) of the sea. To this end, the Health Examination is conducted in two stages, as shown in Fig. 2. The figure also shows the processes of investigation interwoven with the collection of basic information on estuary which will be needed for comprehensive analysis of the collected data and assessment of the health of the sea, and for subsequent decisions on directions to pursue in identifying methods for maintaining and restoring healthy conditions.

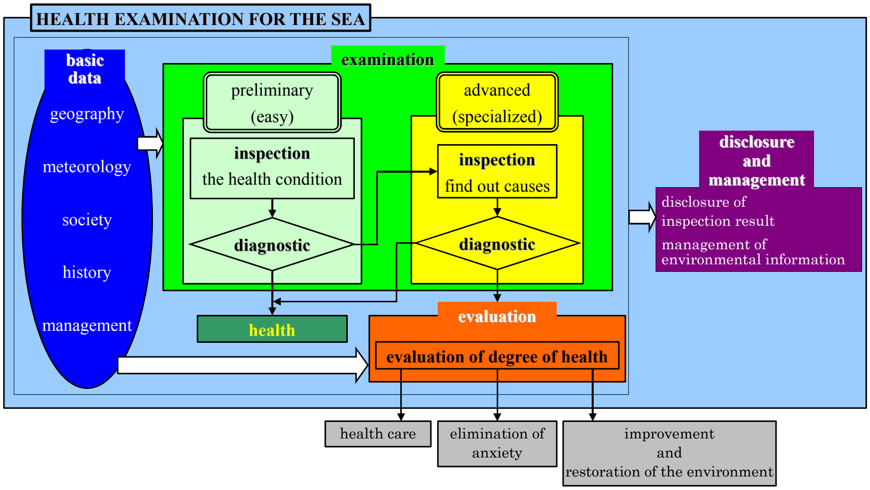


Figure 2: The structure and process of the Sea Health Examination.

The goal of the collection of basic data is to identify the characteristics of the estuary. Items for investigation include geographical features such as topographical and geological features, social considerations such as use of the surface of the water as well as land use in the area, historical background, and also characteristics of the administration of the area.

The actual examination process begins with the preliminary examination, which focuses on grasping a general overview of the health situation and involves information that can be gathered by simple methods so that we are able to obtain a wide range of information continuously. It is important here that one can easily reach a judgement on the health of the sea based on the individual information items collected, and that the criteria for judgement be simple so that symptom indicating poor health is not overlooked. With this in mind, three items concerning the stability of the ecosystem and five items to provide a view on the smoothness of the materials cycle have been selected for examination. To further ensure the accuracy, we have selected more detailed check up index items on which information can be readily obtained.

The advanced examination aims to elucidate the causes for any items found not to be healthy, and it is, therefore, a more specialized type of examination. The individual examination items need to be selected from areas involving physical, chemical and biological factors with the purpose of identifying factors that disturb conditions in the ecosystem and the materials cycle.

Overall an assessment is made of the level of health, and the degree of harm incurred in items found to be not healthy. It is desirable that, ultimately, the examination results will equip us with sufficient basis to make proposals for rectifying problems and for improving the environment.

5 Preliminary examination method and its practice example

We will now look at the method for conducting the preliminary examination and examples of its implementation. We introduce the example in Ise Bay. The location of Ise Bay is as shown in Fig. 3.

The "biotic composition" of the ecosystem first examines "fish catch and its compositions", shown by habitat. The data for catch by species are given in the Ministry of Agriculture, Forestry and Fisheries' annual statistical report, and the figures are available for the catch by estuaries. Although the volume of catch is not synonymous with the volume of resources, one may predict that, as long as the form of coastal fishing does not go through any drastic change, there is a certain correlation between them. On the basis of this assumption, we are able to understand whether an ecological changes are taking place or not by identifying species whose habitat has moved from one spot to another, by studying the changes in the catch by species, and by studying the changes in the volume of catch and catch composition.

Fig. 4(a) shows the changes in the ratio of each classification group of the catch of 20 years in the past in Ise Bay as an example. In the case of Ise Bay, the species composition has shown change. This change is caused by the decline in the pelagic fish catch which are dependent on resources originated from the open sea. It is judged that the thorough examination is necessary because there is a possibility that the stability of the ecosystem is ruined for this case.

Another item in the "biotic composition" is "distribution of the benthos", which is strongly linked with habitat and is an element supporting the base of the food web. Although conducting research on the benthos requires specialized knowledge, it may be made feasible by developing some kind of observation support manual to assist the those conducting surveys and focusing on index species appearing only in normal environments and on those which are most commonly seen so that these manuals could be a handy support for those conducting observation along the beach-line.

The second diagnostic item, "habitat", is used to determine the level of the "natural state" of the tidal flats, seagrass beds and shallow water areas. Information to determine this is taken from figures by the Ministry of Environment. One possible parameter for determining how close to their natural state of the tidal flats and seagrass beds are can be obtained from figures for the fraction of the area of the tidal flats and seagrass beds lost from the area in the year chosen as the base year, and the fraction of the lost area against the area of the individual estuary. The extension of the coastline by construction is represented by the fraction of artificial beach, natural beach and artificial coast in 1993 (Fig. 4(b)), respectively. "Artificial beach" is defined as a "beach with artificial objects placed in its intertidal zone", and artificial objects placed in the zones covered by water. About 60% is an artificial coast in Ise Bay, and it is judged that the thorough examination is necessary because there is a possibility that the stability of the ecosystem is ruined for this case. Apart from these, the information on items such as land reclamation, dredging and embankment construction needs to be considered as part of the basic information.

The third of the diagnostic items is “living space”. Here, “harmful materials” and “bottom layer oxygen deficiency” are the determining factors. Information on harmful materials is taken from the results of water quality conducted by local government in the public-use water domain, and the Ministry of Environment’s Chemical Material Environmental Safety General Examination, both of which are available to the public. The datum for acceptance is that the amount of harmful material in question does not exceed environmental standards, but attention should also be paid to any reports of birth deformities and so on. The degree of oxygen deficiency is determined by examining the concentration of dissolved oxygen in the bottom layer. For this purpose, we use the water quality monitoring data in the public-use water domain. The level at which water is defined as oxygen deficient is 4.3mg/L, which is the level at which it is considered that the survival of organisms begins to be affected. Oxygen deficiency is judged by the ratio for the number of the point showing oxygen-deficient water to the total monitoring points of the estuary.

Fig. 4(c) shows this ratio in Ise Bay estuary. The monitoring point of about 60% or more every year shows the oxygen depletion, and always influences on the living organisms in this estuary. It is judged that the thorough examination is necessary because there is a possibility that the stability of the ecosystem is ruined for this case.

Of the five diagnostic items under the second pillar, “smoothness of materials cycle”, and The “primary production” item requires phytoplankton abundance or chlorophyll concentration, but because these parameters have not been employed as monitoring items in Japan, we selected the transparency data and the number of red tide occurrences as indicators of primary production. This method has the advantage of being easier to handle because the accumulation of biological information is comparatively low. For transparency, the results of water quality monitoring in the public-use water domain are available, and also the method for monitoring is rather simple. The disadvantage is that the transparency is influenced by the condition of the light and changes in the primary production at the same time, making it necessary to identify which is responsible for the change so that evaluation cannot be made simply from the observation results.
With red tides, knowing the number of occurrences alone is not enough. We also need to obtain information on the time, the duration and the details of species composition. For our current purpose, however, we have used just the number of occurrences, obtained from the White Paper on the Environment and other sources. The number of occurrences of the red tide in Ise Bay was shown in Fig. 5. The red tide has occurred every year, it is judged that the thorough examination is necessary because there is a possibility that the smoothness of materials cycle is ruined for this case.

“Load” is determined by examining the “load input” to the estuary. “Load” has various origins: coming from the atmosphere, the open sea, and the sea bottom. Combined, it is likely that in estuaries, the total loading has already reached to the level which we may not ignore. Here, we only use the load input which can be estimated on the basis of such factors as the flow rate of river and water quality. Loading can also be estimated from the population, the amount of industrial products shipped and the ratio of sewered areas. In recent years, due to the dissemination of sewerage systems and the conformance to regulations on wastewater discharge, the input loading has either remained steady or decreased. However, the absolute volume of the input loading needs to be examined in connection with the scale of the estuary and the current velocity field.

The item "water exchange" requires the water quality and physical processes both inside and outside the estuary. Considering this, we may examine the changes in the volume of the water exchange by using tidal amplitude as the index. Observation results for tidal amplitude in the bays can be obtained from the automatic tide-gauge stations operated by organizations such as the Meteorological Agency and the Maritime Safety Agency.

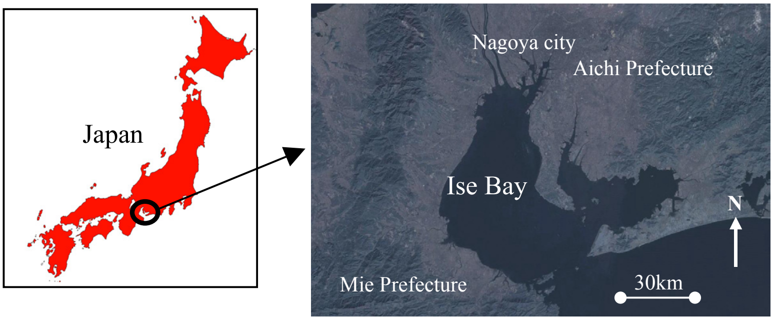
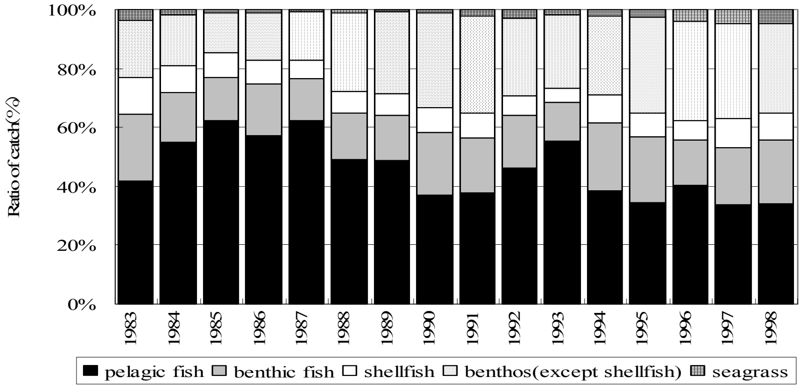


Figure 3: The location of Ise Bay.

The indexes for the item "decomposition–sedimentation" are the "benthic environment" and "DO consumption in the bottom layer". The index of benthic environment is the amount of the sulfide in which two situations –"Deterioration of the bottom quality" and "Formation of the oxygen depleted water"–. For the DO consumption in the bottom layer, we will use the same items as those used for the "living space". But in the case of the "decomposition–sedimentation" item, the focus is on the amount of the oxygen needed for decomposition of organic matter. Testing will therefore will need to be done to identify anoxic conditions.

Since we cannot collect data for the "removal (catch)" item on the feeding activities of sea birds living along the coastal area, here we will confine the focus of attention to the fish catch, the artificial removal of the benthic fish species which are closely linked to the materials cycle and food web formation.



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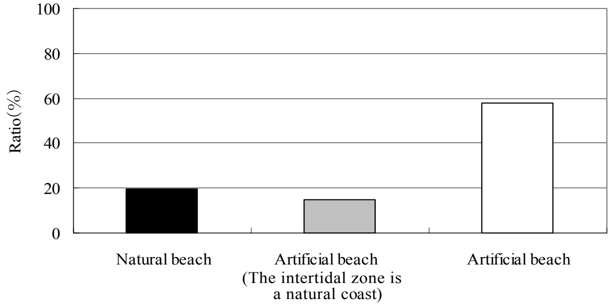

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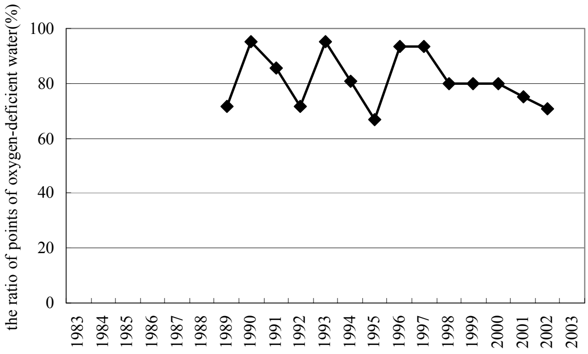

(c)

Figure 4: Result of the preliminary examination in Ise Bay. (a) The changes in the ratio of each classification group of the catch, (b) the fraction of each type of beach in 1993, (c) the ratio of the number of samples registering less than 4.3mg/L in Ise Bay.

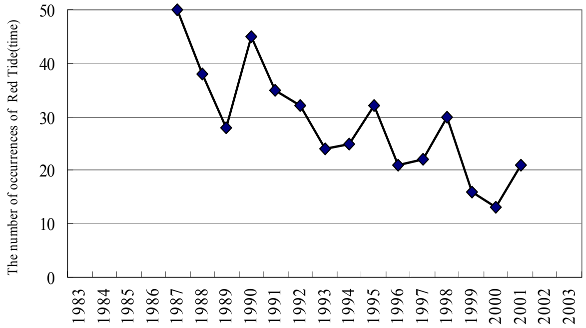

Figure 5: The number of occurrences of Red Tide.

6 Conclusion

Currently, the search for a methodology for the Sea Health Examination is still under way, and we have presented here only examples of the preliminary examination. It is still necessary to further establish methods for the advanced examination that will identify levels of health condition and its causes if the condition is judged to be bad, and then eventually identify directions to proceed to find remedies to cure the illness.

We have also discovered that, even though we have only taken into account comparatively large estuary, there were still discrepancies between the environmental data obtained, and those data were not suitable for producing assessment results at the same level of accuracy. While it is important in conducting environmental monitoring to share, accumulate and make accessible the obtained information, it is also important to prevent only the end figures remaining, with the all the detailed meta data lost. We need to establish a system that incorporates provisions for ensuring that Sea Health Examinations are based on data of uniform quality and accuracy.

References

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