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Application of GIS Techniques to the Preliminary Step for Estimating the Effect of Artificial Reefs*1

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The present report shows an example of the applicability of the GIS (Geographic Information System) in marine science, and assesses the influence of environmental factors on the distribution of fish around artificial reefs. The fish distribution and environmental data were collected from the pilot study area in the Japan Sea off Nagato, Yamaguchi prefecture. One of the most effective functions of this new technique for the present purpose is to help visualize and understand the spatial distribution of fish and relevant environmental factors. Important highlight information that must be taken into account for further data analysis and project development is illustrated in Fig. 5. The extracted detailed information is described in the present report.

1 Introduction

The establishment of methods for assessing the influence of various factors on coastal fisheries for better resource utilization is a matter of urgent necessity.

A number of artificial reefs have been constructed in the coastal area of Japan for the enhancement of coastal fisheries resources.[1-3] In spite of this fact, there are few papers describing the spatial distribution of the resources in relation to the environmental factors, because it has been difficult to collect time-and-space dependent changes in fisheries data and to visualize and quantify their relation to oceanographic and environmental conditions. Acoustic data are the most practical as they can be economically collected in real time to express the distribution of fish.[4] It is natural to examine the relation of the obtained results to the following environmental conditions: water temperature, salinity, dissolved oxygen content (DO) and bottom topography.

Geographic Information System (GIS) techniques, which are widely used in land use planning and the processing of satellite images,[5] were adopted in the present

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studies as a new tactic for the preliminary step in assessing the influence of artificial reefs on the coastal fish using acoustic data, because there are many similarities to land use data and satellite imagery. [6]

The present report aims to show the applicability and effectiveness of this method for marine science.

2 Materials and Methods

2. 1 Positions of artificial reef clusters

In the present study, the area off Nagato along the Japan Sea coast of Yamaguchi prefecture, in which many large-scaled artificial reef clusters have been built, was chosen as the study area. The pilot area is located in the eastern part of this area (Fig.1). To verify the exact distribution of the artificial reefs, a preliminary survey was conducted using the side scan sonar (Klein N530, 500 kHz) and a laser position fixing unit (Atlas, Ltd.) in July and September of 1992. To examine the distribution of the clusters in the pilot area, the survey lines were set at 200 meter intervals nearly parallel to the coast line as indicated in Fig.1. In order to accurately measure the positions of the artificial reef clusters, the surveys were conducted from a boat moving at the speed of 3.5 knots, taking the effect of current and bottom topography into account. The ship's position was measured at 10 second intervals by a laser position fixing system (POLARFIX) in Fig.2, which can provide a position with negligible error and variation. [7]

The side scan acoustic data were first recorded as the relative position between the vessel and tow-fish. These data were then used to prepare an accurate chart of the component blocks of the artificial reef clusters. With the assistance of these data of the corrected positions of the tow-fish at specific times, we have made a mosaic chart of the component blocks of the artificial reef clusters, using the echogram of the side scan sonar. The recording range of the side scan sonar was set to 150 m on each side (300 m on both sides) with a 100 m overlap in order to prevent missing any component blocks.

2. 2 Acoustic and oceanographic survey

The main acoustic survey and oceanographic observations were conducted by the research vessels, "Kuroshio (119 t)" and "Kuroshio No.2 (16 t)" in May and October of 1995. Acoustic information was collected using a Furuno FQ-70 (50 kHz, 200 kHz) quantitative echo-sounder connected to the GPS systems. A SONY PC208A eight-track DAT recorder was used to store the analog output from the echo-sounder. The acoustic equipment was calibrated just before the start of every survey cruise using a 38.1 mm diameter tungsten carbide calibration sphere. [8] Echo integration included all layers from the 10 m layer to the sea-bed. The sounder was operated with a 0.6 ms pulse length and 2 kW transmit power.

An ESDU (Elementary sampling distance unit) was defined as 75 m. A systematic sampling design was applied with parallel transects separated by 200 m each.

The oceanographic information was collected at the stations indicated in Fig. 1 .

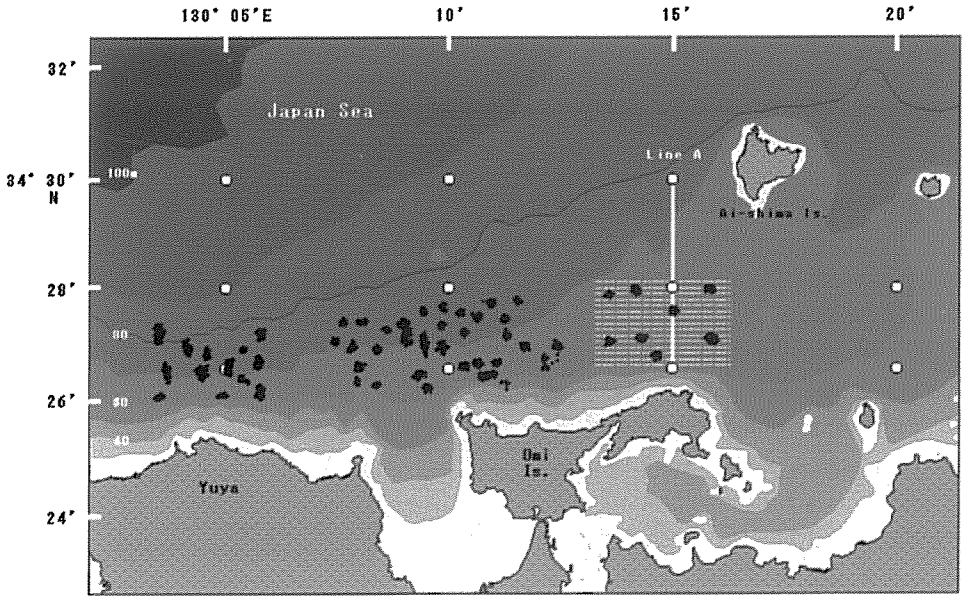

Fig. 1. An outline of the study area and its vicinity, off Nagato in Yamaguchi prefecture showing the location of artificial reef clusters, transects (— —) and CTDO casts (○).

The temperature, salinity, dissolved oxygen content (DO) and density information from the surface to near sea-bed were registered using a SeaBird SBE-19 CTDO.

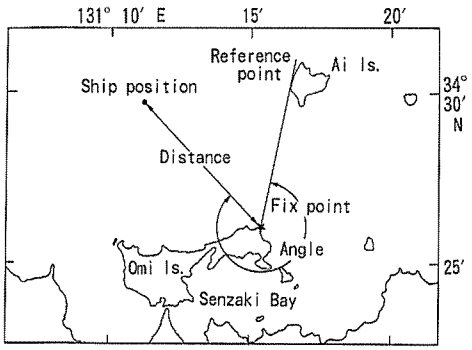

Fig. 2. Location of the points of the laser position fixing system.

2. 3 Geographic Information System (GIS)

GIS may be defined as the integration method of computer hard and soft-ware with spatially referenced digital data so that new spatially related output is produced by storage, retrieval, manipulation, and analysis of the data.[9] The overlay technique is one of the most important functions in the GIS, which can allow us to obtain the fully visualized multi-dimensional spatial characteristics of several independent data sets. This approach also provides an effective method for understanding the relationship between acoustic and other data.[10] As already mentioned, this technique was adopted as the preliminary step to analyze the relation between the acoustic data and environmental

conditions for the purpose of determining the points to which attention should be paid during the analysis.

3 Results and discussion

3. 1 Detection of artificial reef clusters

The principal aim of the present study is to show the effectiveness of the GIS in the analysis of the effect of artificial reefs on the distribution of fish, based on the environment conditions, which were modified by the artificial reefs. A short description of the planned and detected distribution of the component reefs is as follows. According to the plan, 8 large-scaled artificial reef clusters (7 of high construction and one scattered, each within a radius of 125 m around the planned center, 6,396 m^3 of total volume covered) were constructed in 1984 to 1989 in an area covering 3,750×2,500 m on the sea-bed at 55 to 62 m deep, as shown in Fig. 3.

As many as 2,172 component blocks of various types were reported to be placed in the pilot area. Our side scan survey detected 96 % of component blocks. All the center blocks were found approximately at 186 m northwest of the planned positions.[11]

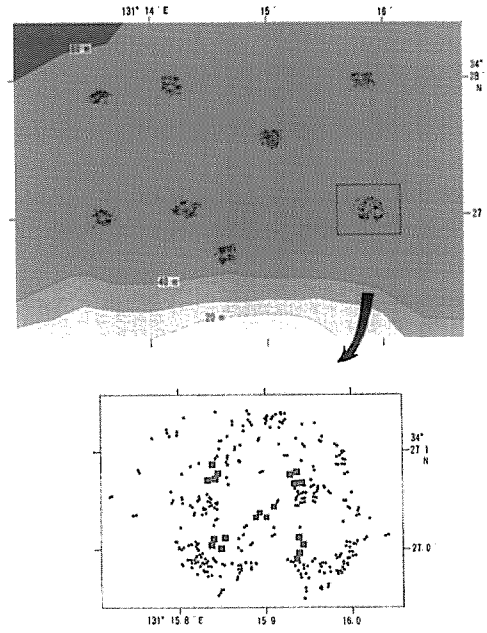

Fig. 3. Detected distribution of the component blocks of the 8 reef clusters in the pilot study area. Dotted points indicate the positions and distributions of component blocks actually detected.

3. 2 Oceanographic conditions

A short description of the vertical distribution of temperature and salinity is initially given for reference, because the layer map drawn using the GIS technique in Fig. 5 can not cover the vertical section of the respective factors.

Figure 4 shows the vertical sections of temperature and salinity along line A in May and October of 1995. In May, the temperature showed a small vertical difference ranging from 16.55℃ in the surface layer to 15.95℃ near the sea-bed. Salinity showed high values when the local mean was taken into account that ranged from 34.40 in the surface layer to 34.60 near the sea-bed. Along with these findings, flowing of higher density water near the sea-bed towards the coast was suggested from Fig.4. In October, on the other hand, the temperature showed a relatively large vertical difference, from 21.9℃ in the surface layer to 20.7℃ near the sea-bed.

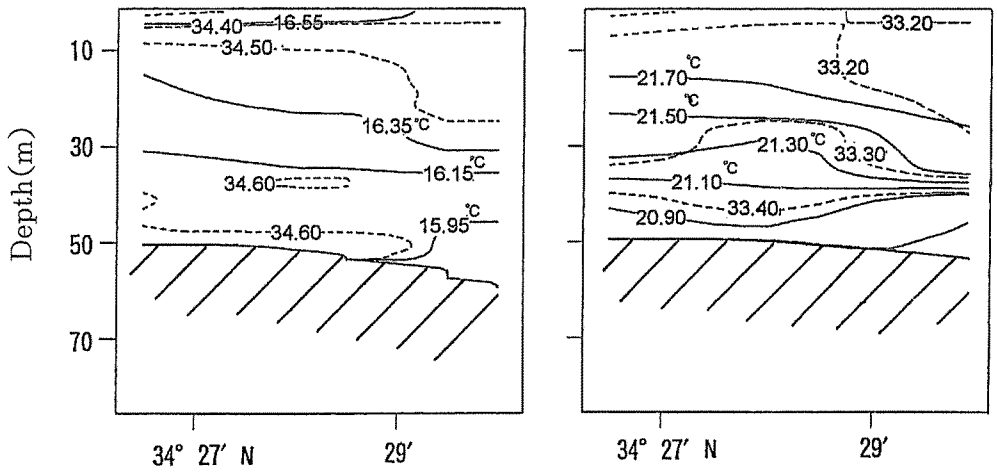

Fig. 4. Temperature (—) and salinity (– – –) sections along line A in May and October of 1995.

3. 3 GIS graphics

The important preliminary step to examine the effect of artificial reefs on the distribution of fish is the choice of characteristic variables and the examination of their spatial distribution. In the past, it was not in common to examine, stratify and screen the data before the analysis. This may be due to the difficulty in illustrating the related factors in an easily understandable form all together within a reasonably short time. The GIS technique is one of the most suitable tactics for this purpose as the reader can easily understand the results shown in Fig.5.

The bottom topography, including the distribution and form of the artificial reefs, is shown in the floor of Fig. 5. This is probably the most basic component that will cause heterogeneity in the distribution of fish, through that in environmental conditions. The induced result, which is the distribution of fish, was picked up as the area back-scattering strength (SA) using the quantitative echo-sounder. It is shown in the layer just above it. The results differed according to the months. In May, no correspondence could be found between the reef locations and SA, due to the rather uniform distribution of SA. These data were not suitable for the analysis of the relation of SA to any of the environmental factors, when the distribution of SA on a very small scale considered. In contrast, the October results showed a good correspondence between the reef locations and high SA, though some discrepancy was found between the size of the reefs and SA.

Analysis based on GIS always includes other manifold factors: for example, physical and chemical environmental ones. Here, the temperature, salinity and dissolved oxygen content at a 40 m depth were chosen as the

examples of the physical and chemical environmental factors. The first one is one of the representatives of the physical factors. The second one is a chemical one of conservative nature, and the last one is also chemical one, but changes according to the conditions and sometimes limits the distribution of fish. The distribution of the water density σ_t is illustrated for the purpose of examining the possibility to using it without losing important information, when the number of drawable layers is limited in case of adding some other information of necessity from other stand points.

No factors suggested the presence of clear water mass boundaries or discontinuous water masses. This fact meant that there was no need to treat the data after stratification into certain sub-groups. The gradient mainly in the N-S direction was found in both of the two factors of oceanographically fundamental importance, the temperature and salinity, suggesting an inverse relation between them. These facts meant that, if one of them was adopted as an explanation variable, it was less probable that the other would be adopted as the second one. The choice of either of them as an explanation variable should be carefully done based on the results already found in other reports. On the contrary, the dissolved oxygen content showed a decreasing trend towards the east without any stagnant areas. From this trend, it was not found out the clear relationship between SA and dissolved oxygen content.

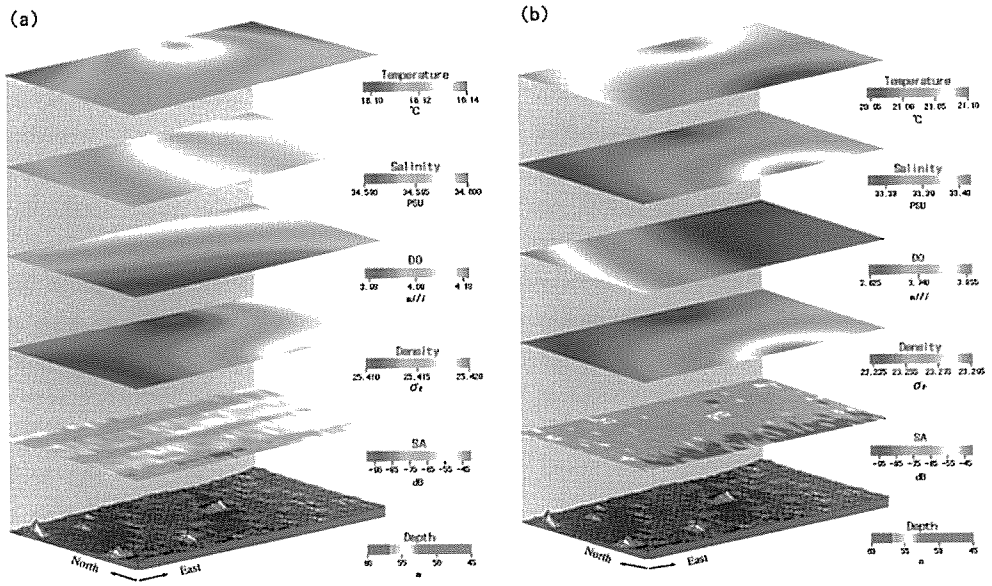

Fig. 5 . Distribution of the area back-scattering strength (SA) with bottom topography including artificial reef clusters and some representatives of environmental factors on the 40 m plane.
(a): May 1995 (b): October 1995

As described above, the application of GIS techniques makes it possible to easily provide these preliminary considerations, in other words, to estimate the necessity of stratification and /or exclusion of data in some limited spots prior to the detailed data analysis.

In summary, it may be concluded that the introduction of GIS techniques into marine science makes it much easier to find valuable information, to which full attention should be paid. The potential of the GIS technique has been demonstrated by mapping and analyzing artificial reefs and the distribution of fish around them. Proper use of the GIS is expected to improve the reliability of the analysis of results in which the spatial distribution of the original data may not be taken into account.

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人工魚礁設置効果評価への地理情報システムの応用

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人工魚礁漁場に生息する海洋生物の空間的分布に関する情報を計量魚探機を用いて収集し，さらにそれに関連する環境情報などをGIS技術によってデータの統合化を図ることにより，人工魚礁設置の効果評価に対するGISの応用を検討した。対象とした人工魚礁漁場は山口県長門海域の大規模人工魚礁群である。用いた資料は1992年から1995年にかけて行ったサイドスキャニングソナーとレーザ測距儀による魚礁設置位置の精密調査，計量魚探機による音響資源調査，CTDOによる海洋環境調査によって得られたデータである。これらの結果を用い，魚礁に蝟集する魚群と海洋環境要因（水温，塩分，溶存酸素量，海水密度σ_t，海底地形）との関係をGIS技術を用いて可視化し，海域の層別化あるいは特定部分を分けて扱う必要性を検討することができた。