POLISH ASSOCIATION FOR SPATIAL INFORMATION
ANNALS OF GEOMATICS 2008 ❍ VOLUME VI ❍ NUMBER 1

USAGE OF GEOSPATIAL METHODS IN DETERMINATION OF PELAGIC FISH STOCK DISTRIBUTION

WYKORZYSTANIE METOD GEOPRZESTRZENNYCH W USTALANIU ROZMIESZCZENIA POPULACJI RYB PELAGICZNYCH

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Keywords: Pelagic fish stock distribution, geospatial interpolation
Słowa kluczowe: rozmieszczenie populacji ryb pelagicznych, interpolacja geoprzestrzenna

Introduction

Almost 40% of the area of the Adriatic Sea (57 000 km^2), including territorial water and the exclusive economic zone, belongs to the Republic of Croatia. The Croatian coastline of the Adriatic Sea is heavily intended, with 1244 islands, rocks and cliffs. However, the Adriatic Sea is one of the richest seas bordering the Mediterranean, with biological resources that have a great importance for the Croatian economy.

One of the important economic activities in the Adriatic Sea is a pelagic fishery, which has a long tradition in Croatia. Because fishing has a direct impact on the fauna and flora of the sea, scientific estimation of the spatial distribution and abundance of pelagic fish in the Adriatic Sea has been undertaken for more then 60 years. Recently, there has been a special effort in Croatia to use a hydro-acoustic methodology, supported by objective analysis and GIS technology, to obtain information about the commercially important pelagic species in the Adriatic Sea, their geographical distribution, abundance estimates and population structures.

In this paper is discussed how different segment lengths of integration along measurement transects influences the estimate of the spatial distribution of the pelagic fish stock.

Methodology

During echo surveying, additional parameters have been collected, including temperature profile, salinity, oxygen levels, phytoplankton, zooplankton and fish samples using small pelagic net at discrete points along the echo surveying transect. Echo surveying was done along transects, paths of interest, whose length and orientation were defined from previous knowledge about fishing, oceanographic properties and the Adriatic Sea morphology, using GIS technology.

The definition of shape, size and orientation of the transects and the distance among them in this investigation was controlled by the main objective to gather useful results using the smallest manpower and monetary cost as possible. This was relatively difficult because the Croatian coastal region of the Adriatic Sea is much intended, with many narrow and long islands and channels (Figure 1). During this process next two facts were taken in account:

1) Biological resources from one side to the other of long, narrow islands, or in two neighbouring channels, can be very different in spite of the relatively small geographic area, and
2) As pelagic fish live in big groups and migrate relatively fast from one marine region to another, the same group can be registered multiple times during measurement by echo sounder along long transects and where transects are close together.

Objective kriging was used for spatial interpolation of the measured data and generation of spatial fields of fish stock distribution. For describing and comparing the spatial distribution of small pelagic fish, ordinary kriging method was used, as it presents an optimal method of interpolation and provides the best linear unbiased estimate of the variable at a given point (Deutch and Journel, 1992; Journel and Huijbregts, 1993). It is linear because estimate values that are weighted linear combinations of available data; unbiased because the mean of the error is zero and the best because it minimizes the variance of the errors. Essentially, it is necessary to know the spatial variation in the data during kriging interpolation. This method solves the problem of calculating semi variance as a measure of the degree of spatial dependence between samples. It is known that the semi variance value is close to zero where points are very close, and it increases as the distance increases until it reaches maximum at some certain distance away from a point. This distance, at which semi variance reaches its maximum value, defines the end of spatial homogeneity in the data. Therefore, only the samples in the local neighbourhood within the area of homogeneity are used during interpolation. This assumes that the local means are not necessarily close to the population mean. The kriging method is often termed BLUE (best linear unbiased estimator). This method has a disadvantage, as there are no capabilities to recognize barriers, such as narrow islands and channels, of which there are many in the coastal area of the Croatian part of the Adriatic Sea.

Kriging method was widely used for interpolation of marine spatial data (Dadić, Srdelić and Ivanković, 2000; Dadić, Srdelić and Gržetić, 2001).

Graphic presentation of the interpolated fields and variance obtained during the kriging interpolation enabled evaluation of spatial homogeneity of the fish data (Graff et al., 2003).

The digital map of the Adriatic Sea coastline was created using ArcGIS. All data of related oceanographic parameters were stored in MEDAS (Marine environmental database of the Adriatic Sea), developed at the Institute of Oceanography and Fisheries in Split using the ORACLE 10i database management system (Dadic and Ivankovic, 2005).

Results

For the purpose of investigating echo survey of small pelagic fish, the Croatian part of the Adriatic Sea was divided into two main regions as follows: Channel waters and Open sea covering Croatian territorial waters and the Exclusive economic area (Fig. 1). As the Republic of Croatia has recently recognized an exclusive economic zone in the Adriatic Sea, one aim of investigation is to analyse the importance of this area for fish food production in Croatia.

Based on previous investigations, transects in the open sea were chosen to be almost square like, with 10 nautical miles (nm) distance between them. As channel zones were mainly defined accordint to the sea and islands morphology, there is a big difference in size and shape of measuring transects (Fig. 2).

The distance between transects in the open sea was about 10 nm, except the first and last ones, but their lengths and shapes were different, depending of the position and shape of island shore lines from one side, and the borders of territorial waters and the exclusive economic zone on the other. It is interesting to note that the transects of echo-surveying were not transversal to the orientation of the Adriatic Sea, being orientated along a line 55–225^0 toward North.

One of the problems was how to organize the survey paths of the research vessel in the shortest period, to get the most harmonized data as possible with minimum cost. To achieve this, echo-survey routes begin from the northern part of the Adriatic Sea following the inner or outer edges, and then pass through the middle part of each zone from the southern to northern parts of the Adriatic Sea or the opposite way. In channel areas, research routes were derived from channel shape and sea morphology and they have a more complex shape.

Original data obtained by the instruments were measured with a distance of 1 nm along the transects. During interpolation of the original data, an additional five data sets were created, each with data interpolated at different distances (2.5, 5, 7.5, 10 and 12.5 nm) along the survey transects, in order to study how different distances between stations influences the reconstruction of the spatial fields of fish population.

All calculations were done on the total fish stock population along transects, and the reconstruction of corresponding distribution of spatial fields (Fig. 3). It is obvious that extension of the distance between stations causes smoothing, with lower maximum and higher minimum measurement data at the stations.

In addition to these results, it was necessary to consider the reliability of the distribution of the pelagic fish stock population obtained. Calculation was done using the semi-variogram as a measure of spatial homogeneity.

Calculations of homogeneity and isotropy of all subsets of the data was done using semi-variograms (Fig. 4) with an appropriate linear trend model. The x-axis on the diagrams, distance between stations (known as a lag distance), is presented in degrees (60 nm).

The semi-variogram shows that shows the largest area of homogeneity is obtained from the original data set with a distance of 1nm between measuring stations (up to 15 nm). The results of the semi-variogram become coarser with a smaler distance of homogeneity where the distance is extended between measuring stations (Fig. 4). Figure 4A to 4E shows that homogeneity has been preserved for distances between stations not larger than the distance along the measuring transects (10 nm).

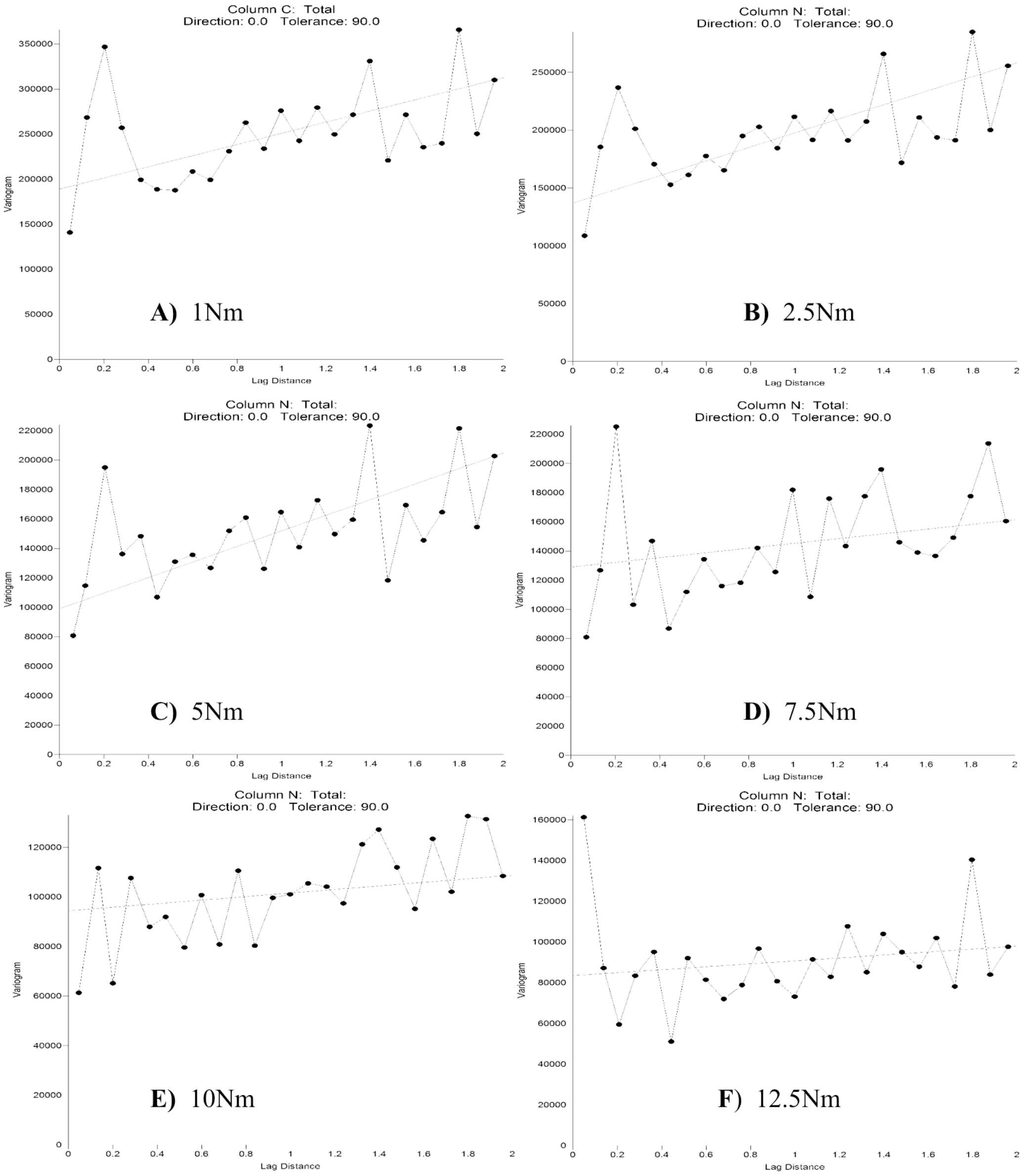

Figure 4. Semi-variograms with corresponding linear model trends respectively for distance 1, 2.5, 5, 7.5, 10 and 12.5 Nm among stations along measuring transects

For distances between stations along transects larger than the distance between transects (Fig. 4F), there was no homogeneity within the data. In this case, objective kriging could not be used for assessment of the spatial fields of stock population, as the variance of errors obtained becomes too high and reconstructed fields become artificial.

Where data have been interpolated from measuring stations with a different distance between them (from 1nm up to 10nm) along the transects, the resulting spatial field become smoother, but total stock of pelagic fish population does not vary significantly and the corresponding spatial fields of fish stock population are, therefore, realistic.

It can be concluded that the maximum distance between stations for surveying of pelagic fish stock population in the Adriatic Sea can be up to 10 nm, but for larger distances, the spatial fields become unrealistic.

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Abstract

In the framework of the PELMON Project, monitoring of pelagic fish stock was performed over twenty days in September 2007 by the research vessel Bios in the Croatian territorial waters and Exclusive economic zone of the Adriatic Sea. The cruise was performed in transects, organized as square like profiles with 10 nautical miles distance between them. Fish stock measured by special type of fish finder echo sounder and, in addition, some other oceanographic parameters. Distance between stations along transect was selected from one to twelve and half nautical miles. As pelagic fish migrate relatively fast, in comparison with the bottom fish population, special care was needed in data processing and analysis. Therefore, GIS with objective kriging were useful tools for investigating the assessment of the spatial distribution of the pelagic fish stock population. It was found that the distance among stations along measuring transects could have a significant influence on the quality and precision of the modelled spatial distribution of the fish population.

Streszczenie

W ramach projektu PELMON, przez ponad dwadzieścia dni września 2007 r., prowadzony był monitoring populacji ryb pelagicznych za pomocą okrętu badawczego Bios na wodach terytorialnych Chorwacji oraz Wyłącznej strefie ekonomicznej Morza Adriatyckiego. Tor rejsu przebiegał wzdłuż poprzecznych pasów, zorganizowanych w profile odległe od siebie o 10 mil morskich. Populacja ryb mierzona była za pomocą specjalnego typu hydrolokatora do poszukiwania ryb oraz, dodatkowo, *innych parametrów oceanograficznych. Odległość między stanowiskami w obrębie jednego pasa wybrana została z zakresu od jednej do dwunastu i pół mil morskich. Jako że ryby pelagiczne migrują względnie szybko w porównaniu z populacją ryb dennych, zaistniała potrzeba zachowania szczególnej uwagi podczas procesów przetwarzania i analizy. Z tego względu użytecznymi narzędziami badania oceny przestrzennego rozmieszczenia populacji ryb pelagicznych były systemy GIS wraz z krigingiem przedmiotowym. Odkryto, iż odległość między stanowiskami w obrębie pasów pomiarowych mogła mieć znaczący wpływ na jakość i dokładność wyznaczonego modelu przestrzennego rozmieszczenia populacji ryb.*

UPOTREBA GEOPROSTORNIH METODA U ODREĐIVANJU RASPODIJELE STOKA PELAGIČNIH RIBA

Ključne riječi: Raspodjela stoka pelagičnih riba, geoprostorna interpolacija

Sažetak

U okviru projekta PELMON istraživan je stok pelagičnih riba u hrvatskim teritorijalnim vodama i ZERP-u tijekom dvadeset dana u rujnu 2007. godine pomoću I/B Bios. Kako pelagične ribe migriraju relativno brzo u usporedbi s pridnenom ribljom populacijama posebna pozornost je posvećena načinu mjerenja, te obradi i analizi prikupljenih podataka. Tako su mjerenja obavljena uzduž usporednih „kvadratičnih“ profila s međusobnom udaljenošću oko 10Nm. Riblji stok je registriran "fish finder" ehosonderom uz mjerenje nekoliko dodatnih oceanografskih parametara. U svrhu ispitivanja utjecaja različitih udaljenosti između postaja uzduž mjerenih profila na procjenu ribljeg stoka, tijekom mjerenja su podatci interpolirani na 6 različitih udaljenosti između postaja u rasponu od jedne do dvanaest nautičkih milja. U ovu namjenu su korišteni GIS alati s kriging geoprostornom interpolacijom. Ispitivanja su pokazala da izabrana udaljenost između postaja može značajno utjecati na izgled i točnost procijenjenih geoprostornih polja stoka riblje populacije.

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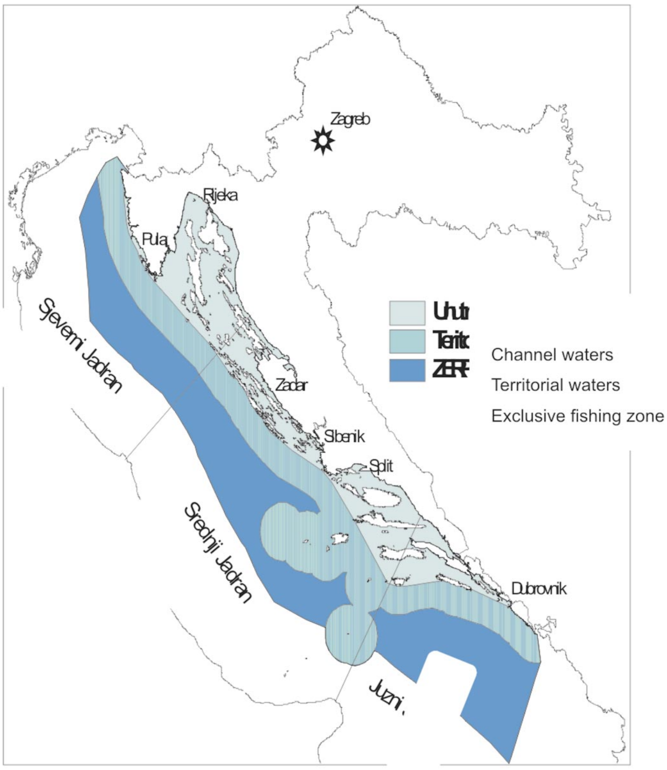

Figure 1. Croatian part of the Adriatic Sea: Channel waters, Open sea waters (Territorial waters and Exclusive fishing zone)

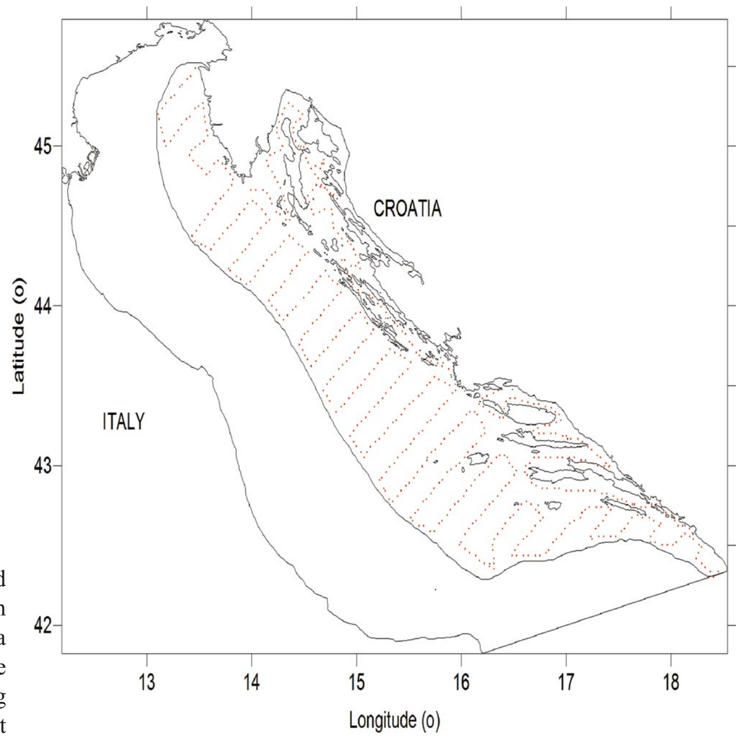

Figure 2. Shape, size and orientation of transects in Channel waters and Open sea waters of the Croatian part of the Adriatic Sea and measuring stations along transect

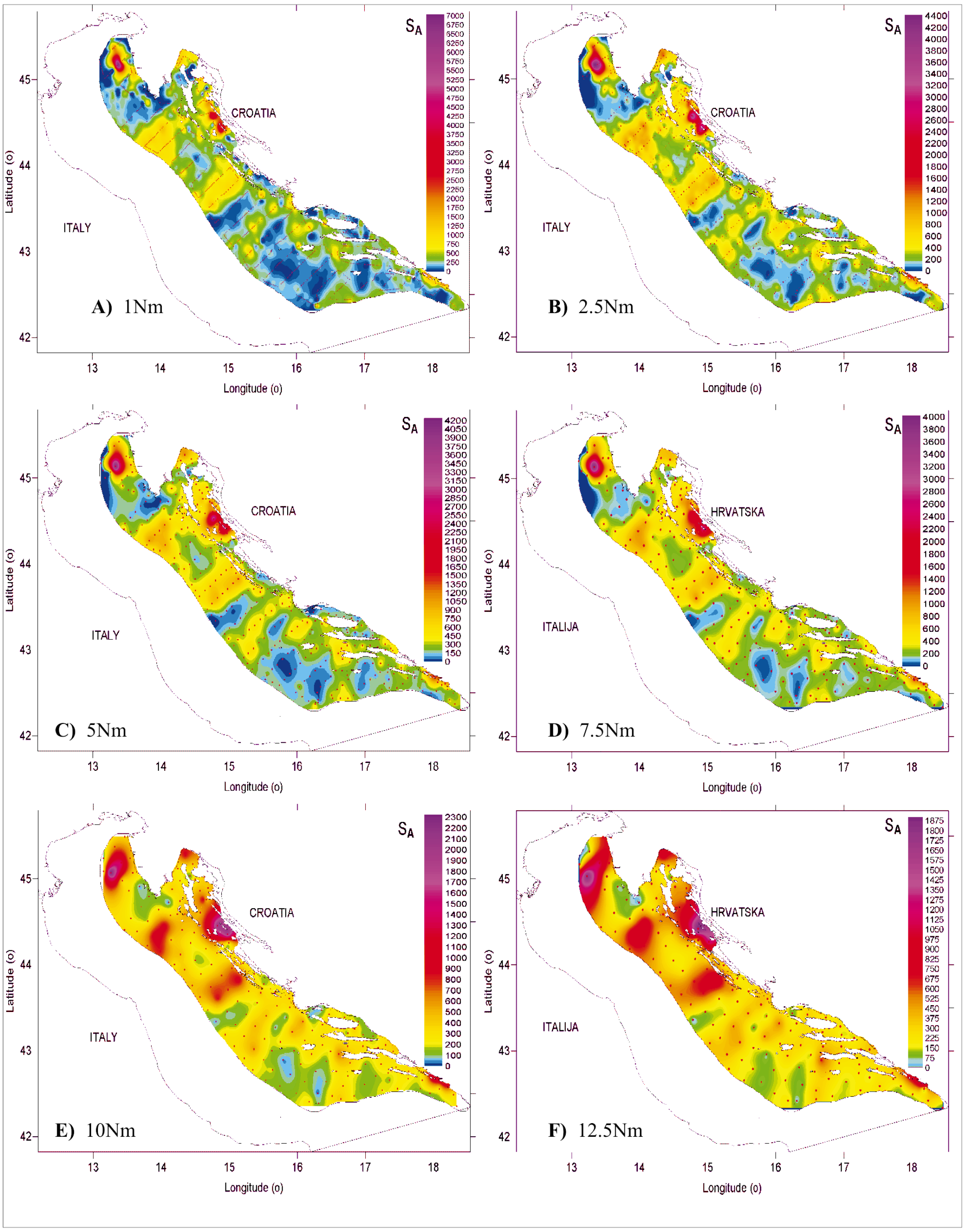

Figure 3. Spatial fields of distribution of pelagic fish population obtained by kriging method of interpolation respectively for distance 1, 2.5, 5, 7.5, 10 and 12.5 nm among stations along measuring transects