

Estimation of capelin larval indices using GIS

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Abstract

An annual larval abundance index is calculated for capelin (*Mallotus villosus*) in the Barents Sea, using data on larval densities in geographic positions. Previously, the estimated capelin larval indices were calculated with a Fortran program were calculated with spline-functions implemented in a Fortran program, a time-consuming process involving manual decisions. In 2005 we estimated new indices for the period 1981-2005 using GIS. A larval abundance raster map was produced in ArcMap 8.3 using IDW interpolation. Raster statistic was used to estimate larval indices. Correlation between old and new indices was 0.993. Both methods were sensible to high values of observed larval densities near the coast, and that is where the two methods differed. The new method seems preferable to the old method since it is precise, brief and more user-friendly, and less dependent on the person doing the calculations.

Keywords: abundance indices, capelin larvae, GIS, ArcMap.

Introduction

The capelin is a key fish species in the Barents Sea ecosystem. Capelin consumes much zooplankton, and is also the main forage species for many larger predatory fish (Northeast Arctic cod (*Gadus morhua*) (Mehl and Yaragina 1992), Norwegian spring spawning herring (*Clupea harengus*) (Gjøsæter, 1995, Gjøsæter & Bogstad, 1998), seabirds and marine mammals (Haug et al, 1995). The capelin stock undergoes large fluctuations. The stock collapsed in 1985-1986, 1992-1993 (Gjøsæter, 1995, Hamre, 1990, Røttingen, 1990), and 2003-2004, primarily because of recruitment failure.

Annual larval capelin surveys in the Barents Sea have been conducted since 1981. From 2004 the larval survey formed one part of the Barents Sea summer ecosystem survey. The coverage of capelin larvae is carried out during May-June, and the aim of this survey is to give a first indication of the strength of the annual capelin larval production.

Larval indices based on this survey were calculated since 1981. Indices were calculated manually from 1981 to 1985, based on hand drawn isolines and planimetry (Alvheim, 1985). A Fortran program package, ITAKS, was used for this purpose between 1987 and 2005. The covered area was delimited by a polygon, and this polygon was divided into a grid with cell size 5 * 6.6 nautical miles. A spline function was applied to interpolate larval densities and calculate the larval abundance index. The degree of spline equation was given the value 5. The method and Fortran program are outlined in (Westgård et al, 1988).

The first two methods described were either totally or partly dependent on manual input and decisions, and were error-prone, time consuming and heavily dependent on operator. The aim of this paper is to present a new method of capelin larval indices

estimation using the GIS tools ArcMap, recalculate the time-series of indices, and compare the values to those obtained with older methods. The new approach is more brief and user-friendly, and less dependent on the person doing the calculations.

Methods

The capelin larval abundance was monitored annually during the capelin larval survey. Capelin larvae catches were made with the high-speed plankton sampler GULF III (Gehringer, 1952), a torpedo-shaped aluminum cylinder with a plankton net mounted in a rack inside the cylinder. A mechanical flowmeter, (General Oceanics model 2030R, <http://www.GeneralOceanics.com>) was mounted in the opening of the GULF, measuring the water volume flowing through. The caught fish larvae were identified, and numbers and length measured. The amount of larvae (A_{cl}) per 1 square meter of surface was calculated with consideration to measured water volume, depth layers and total number of caught larvae (Equation 1)

$$A_{cl} = a_{cl} \cdot \frac{\Delta d}{Fl_{count} \cdot 0.02835 Fl_{ssrc}} \quad (1)$$

Where A_{cl} is scaled total number of larvae per square meter, a_{cl} is caught at the station, Δd is differences between the deepest surveyed water layers and surface, Fl_{count} is measured water volume as flowed through the GULF's opening ($0.02835m^2$), and Fl_{ssrc} is standard speed rotor constant (calibrated to 3000).

Larval distribution maps were produced in ArcMap 8.3. The *UTM* (Universal Transverse Mercator) coordinate system was used. Larval distribution raster maps with grid size 1*1 and 5*5 nautical miles were produced, using *Inverse Distance Weighted* (IDW) *interpolation*. (The method is outlined in <http://www.esri.com>), taking actual annual survey coverage into consideration. The border towards the coast was kept constant from year to year (Fig. 1).

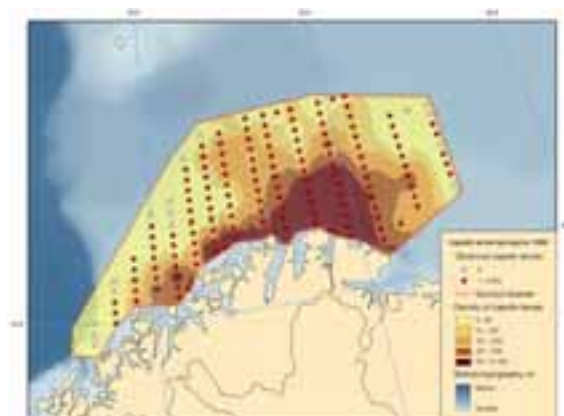


Figure 1. Capelin larval survey in 1999.

Capelin larval density per grid cell was estimated by *Raster statistic*, and summed over the total surveyed area. The capelin larval index was estimated using Equation 2:

$$I = \sum_{i=1}^n A_i \cdot S^2 \quad (2)$$

Where I is index of capelin larvae obtaining as sum of number of larvae per grid cell (A_1, A_2, \dots, A_n) and multiplied by grid size S^2 .

Results and discussion

Capelin larval indices were calculated for the period from 1981 to 2005 (Table 1). The new indices, based on either 1 or 5 square nautical mile grid cell size, were generally higher than those calculated with ITAKS or manually, particularly with increasing index value. Correlations between old (ITAKS) and new (GIS) larval indices are 0.991 (1*1nm) and 0.990 (5*5nm).

Years	New indices 1*1nm	New indices 5*5nm	Old indices
1981*	11.0	10.7	9.9
1982*	10.8	10.4	9.9
1983*	6.2	5.7	9.7
1984*	8.6	7.4	8.2
1985*	11.4	11.2	8.6
1987	0.4	0.4	0.3
1988	0.2	0.2	0.3
1989	7.2	6.7	7.3
1990	14.2	13.5	13.0
1991	5.9	5.4	3.0
1992	10.2	6.8	7.2
1993	4.7	3.6	3.3
1994	0.2	0.2	0.1
1995	0.0	0.0	0.0
1996	2.4	2.3	2.4
1997	5.7	5.7	6.9
1998	13.7	13.2	14.1
1999	41.4	38.3	36.5
2000	18.9	17.5	19.1
2001	12.4	12.6	10.7
2002	24.2	24.4	22.5
2003	12.1	11.3	11.9
2004	2.5	2.4	2.5
2005	7.9	6.8	8.8
Average	9.68	9.03	9.01

Table 1. Capelin larval indices between 1981-2005.

Effect of grid cell size on the new (GIS) method

The distance between stations with Gulf III has varied between 10 and 20 nautical miles, and consequently, smaller grid size than 10 square nautical miles would not be useful when working in the open sea. However, a coarse grid will give a poor fit to the border along the coastline, and since larval abundance is often quite high at the coastal stations this may affect the total index considerably. Two grid sizes were tried,

1 and 5 square nautical miles, to check the effect of grid size. In 22 out of 24 years, the index based on the smaller grid size was equal to or larger than that based on the larger grid size, and the average over all years are 7 % larger (Table 1). It is assumed that most of this difference may be attributed to the above mentioned coastal border effect.

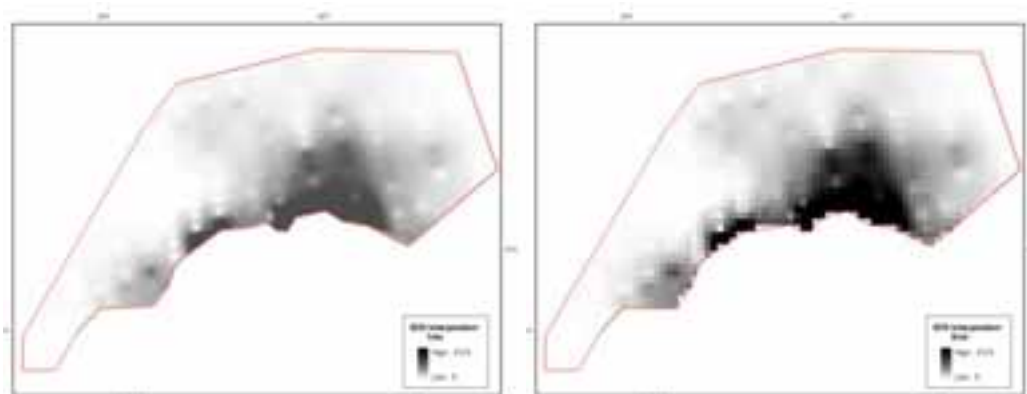


Figure 2. IDW interpolation based on 1*1 and 5*5nm size grid nets.

Comparison of old (ITAKS) and new (GIS) methods

Both methods are sensible to high values of observed larvae near the coast. Since time does not allow for a sufficiently dense sampling grid to find the exact boarder of the larval distribution towards the coast, it was decided to use a constant coastal boarder. It is seen (Table 1) that the new GIS method applying 5*5 nautical miles grid size and the ITAKS method gives very similar results. However, since it was decided to use a constant boarder along the coast, and the GIS method applying a 1*1 nautical miles grid gives more reliable results because of the better fit to this boarder, it was decided to use the latter as a new standard method for calculation of the Barents Sea capelin larval index. The new method seems preferable to the old method since it is more precise, brief and more user-friendly, and less dependent on the person doing the calculations.

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