

Appendix – Remote Sensing

Using remote sensing to determine estimates of secondary production. Part II – calculating the total available biomass as food for mackerel larvae / post-larvae

Introduction

The first part of this appendix, presented in Bremerhaven in January 2001, entitled “Using remote sensing to determine estimates of secondary production” detailed how satellite derived estimates of sea surface temperature (SST) and chlorophyll were used as an input into the copepod egg production model of Prestidge *et al.* (1995). The model was run for two genera of copepod namely *Calanus* and *Acartia*, these being taken as representative of a large and small copepod respectively. The output of the model has units of number of eggs per female per day and as such needs to be multiplied by the number of females present within any one location to obtain the secondary production. Such data can be obtained from the Continuous Plankton Recorder (CPR) survey. This step, as reported in the previous appendix document, resulted in a computed daily egg production. The next step allows the computation of standing stock biomass for *C. finmarchicus*, *C. helgolandicus* and *Acartia* (using data for *Pseudocalanus*) and, once raised by a proportion of the gut contents represented by these two genera, an estimation for the food available to mackerel larvae can be obtained.

Method

From tables 2 and 3 of Lynch *et al.* (2000), the total standing stock biomass of all eggs, nauplii and copepodite stages at quasi-steady-state for a set egg production is given as:

C. finmarchicus = 3174 µg at an egg production rate of 52.08 eggs/female/day at 5°C
Pseudocalanus = 49 µg at an egg production rate of 4.10 eggs/female/day at 5°C

Hence, carbon standing stock biomass is:

C. finmarchicus: $(3174/52.08)*0.33*0.4 = 8.1 \mu\text{g C per egg at } 15^\circ\text{C}$

Pseudocalanus: $(49/4.1)*0.33*0.4 = 1.6 \mu\text{g C per egg at } 15^\circ\text{C}$

using a Q_{10} of 3 for conversion of development time from 5 to 15°C and a carbon content of 40%. This allows direct conversion of computed daily egg production from the remote sensing data to standing stock biomass for *C. fin* and *hel.* (assuming a similar relationship for *helgolandicus* as *finmarchicus*) and taking *Acartia* production as the same as *Pseudocalanus* – both being small copepods.

The CPR data are obtained as numbers (N) per 3m³ (the CPR sample size) as the following “groups” estimated to be made up as follows:

C. finmarchicus V+VI = all stages CV and CVI

Acartia = 100% of CVI, 90% of CV and 50% of CIV

Since only stage VI are mature and only a proportion are females, the following factors need to be applied to the CPR data to give the number of females/litre:

C. finmarchicus: 0.83×10^{-4}
Acartia: 0.83×10^{-4}

based on 25% of both groups being adult females, and allowing for the sample size of 3000 litres. Data for the derivation of these approximate conversions have been used from routine sampling off Plymouth, the 200 μm samples taken on the 1999 Challenger cruise and from historical LHPR sampling in the Celtic Sea and North Atlantic. A final raising factor is included to allow for the proportion of available food represented by the combined biomass of *Calanus* and *Acartia*. Based on gut contents analysis of mackerel larvae, these two species (with an assumed equivalence of the young development stages that cannot be identified to species) represent around 12.5% of the diet i.e., a raising factor of 8.

In summary, the total available biomass as food for mackerel larvae/post-larvae can be calculated as:

$$\text{Food} = 8 \times 0.83 \times 10^{-4} [(8.1E_c)N_c + (1.6E_a)N_a] \mu\text{g C/litre}$$

where E_c and E_a are the remote sensing derived egg production rates per female *Calanus* and *Acartia*, respectively and N_c and N_a are the CPR sample counts for the groups *Calanus* V/VI and *Acartia*, respectively.

Images and ASCII text files (for input into the BPTM) were produced on a monthly basis (January – September) for 1998 – 2000. As the BPTM modelled period is about 2 months of (planktonic) larval / post-larval development, weekly estimates of the food availability were produced by de-convolving each month into daily fields which were then composited. These fields were produced for week 3 – 37 as ASCII text for use as input into baseline runs of the BPTM.

Technical note

Over the SEAMAR BPTM there were many gridpoints not covered by the CPR survey and hence missing data in the calculated food availability field. This was found to be problematic when it came to producing baseline runs using the food availability data as an input. Monthly averaged plots were produced of the CPR data as ascii text within a grid structure over the model domain. Missing grid points were estimated south of 49N by Valdes and north of 49N by Coombs, Halliday and Conway using other data sources such as net catches and crude interpolation. The major data sparse region in the CPR time series was found to be the Bay of Biscay which has great importance for mackerel larvae in the early spring period. Further data holes were also found around coastal zones due to interpolating different size data matrices (SST: 229x132, chlorophyll: 456x266, CPR: 40x23) onto the prescribed BPTM grid size of 155x140. These were filled using averaging of pixels (containing sea rather than the land mask) within a 5x5 box of a missing data point.

Results

Figures 1 – 3 show the monthly average food available to mackerel larvae for the period 1998 – 2000 respectively. There are strong similarities between the different years in terms of the distribution of available food. This is to be expected as the model is driven by the CPR data input which is a long term monthly mean i.e., the CPR data input for e.g., May is the same for all years studied. However there are different values of available food for different years as the CPR data is modified by the multiplicative effect of the production algorithm. For example in 1998 just to the west of the Hebrides there is a region of available food with values around 15 $\mu\text{g C/litre}$. In 1999, although the distribution is similar the patch has a value in excess of 30 $\mu\text{g C/litre}$. In 2000 the patch seems to shrink in size but still retains values close to 25 $\mu\text{g C/litre}$. This implies that straight use of CPR data in determining food availability would mask out subtleties within the interannual variability. The use of remote sensing and hence the Prestidge model is therefore an important step in the modelling of interannual food availability. The monthly images clearly show a progression throughout the year which is consistent with what is expected. In January most of the food is confined to the shelf break regions within Biscay. This is repeated in February and March but with slight increases in the magnitude of the data from 0 – 5 $\mu\text{g C/litre}$ to 5 – 10 $\mu\text{g C/litre}$. This is consistent with models and measurements of mackerel larvae at this particular time of the year with little or no mackerel larvae being observed north of 47N; all of the larvae are confined to the shelf region within Biscay. This could imply that the larvae survival is limited by food. During April food starts appearing on and around the broad UK and Ireland continental shelf. For the rest of the period the available food spills off the continental shelf into the deep ocean regions but is most intense around the shelf break regions to the west of Scotland. Available food around the Biscay shelf break and the Iberian peninsula is present in low concentrations throughout the period but during the summer it is notably absent from the central Biscay region. This could be associated with the low values of chlorophyll which are observed there during the summer months.

Validation

Table 1 shows values of total zooplankton biomass obtained by several field observations which can be used as a comparison with the model output.

Field Obs.	Period	size	Biomass (μgCl^{-1})	location
CH144	July	>53 μm	6 – 23	Shelf edge & adjacent
Batten <i>et al.</i>	Summer	>280 μm	2	Shelf edge & adjacent
Head <i>et al.</i>	June / July	>200 μm	2 – 6	Central NE Atlantic
Joint <i>et al.</i>	May	>280 μm	3 – 12	Goban Spur

Table 1 Values of total zooplankton biomass obtained from several field campaigns

The CH144 cruise are values obtained using both dry weight and direct carbon estimates in the top 100m of the water column. The Batten *et al.* (1999) and Joint *et al.* (2001) data were both taken using the CPR whereas the Head *et al.* (1999) data were taken using a WP-2 net. The total zooplankton biomass over all of the field campaigns fall between 2 and 23 μgCl^{-1} during the summer months (May – August). Looking at the imagery shown in figures 1 – 3 for all years, the values of the food available to the mackerel larvae in the Celtic Sea and off the Porcupine Sea Bight generally range between 2 (purple) and 15 μgCl^{-1} (yellow) with persistent patches of 5

– 10 μgCl^{-1} (blue – green) during this period. There is some slight interannual variability within this pattern with 1999 being a less productive year than 1998 and 2000, according to the model output. The values obtained by the modelling are therefore in close agreement with the data obtained during several field campaigns and should provide a good measure to determine mortality of mackerel larvae.

Conclusion

The copepod egg production model of Prestidge *et al.* has been successfully implemented using RS data as input. The output from the model has been weighted using CPR data to obtain estimates of secondary production. Using the figures for *Calanus* and *Pseudocalanus* published by Lynch *et al.*, together with gut content data taken on board the RRS Challenger cruise an estimate of total biomass available as food to mackerel larvae on a weekly basis has been obtained from the secondary production figures across the entire domain of the SEAMAR model. It must be stressed at this point that the output from the modelling procedure is a product of some rough assumptions but this is the first time that such an exercise has been undertaken. The advantages of using this approach are that it is computationally fast (compared with using an ecosystem model) and that estimates can be obtained across wide spatial and temporal scales (in contrast to point measurements taken by ships). It is difficult however to validate the numbers produced by the modelling procedure except in a broadly qualitative sense. The distribution of available food is consistent with what is expected. For example in the late winter / early spring (Jan – Mar), mackerel larvae are only found around the Iberian and Bay of Biscay shelf regions. When the model output is compared to several field campaigns carried out within the model domain close agreement is found between the measured total zooplankton biomass and the calculated food available to mackerel larvae.

References

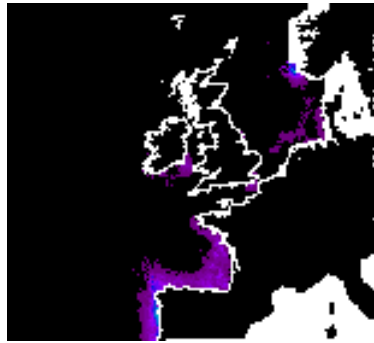
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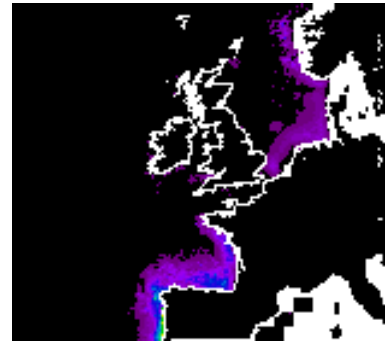
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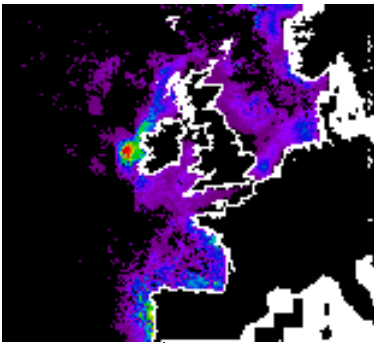
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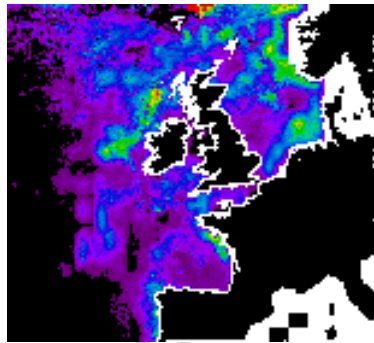
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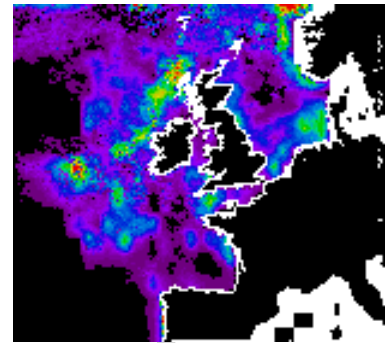
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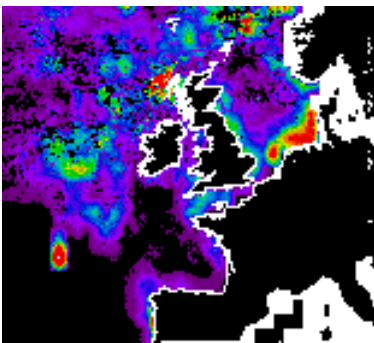
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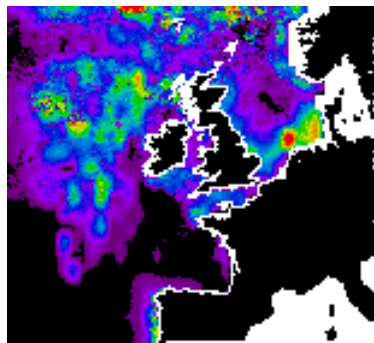
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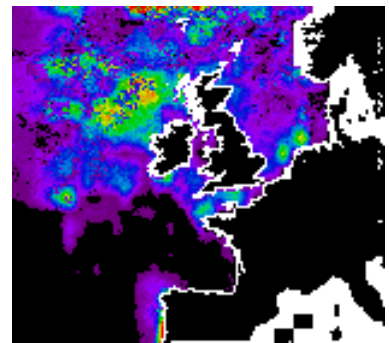
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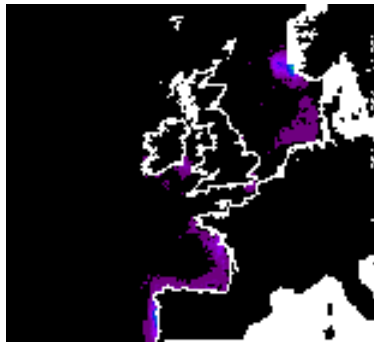
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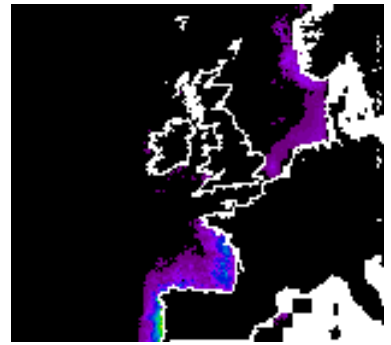
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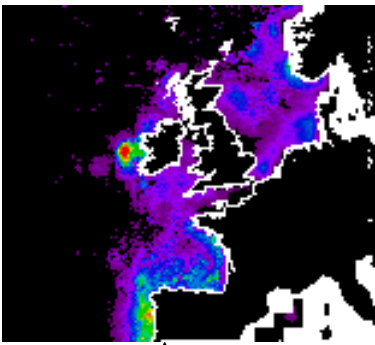
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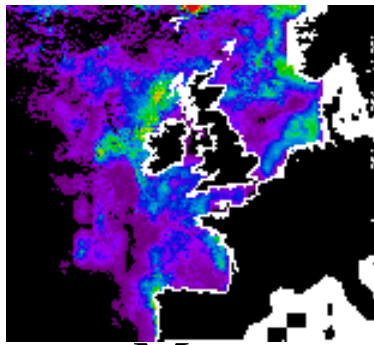
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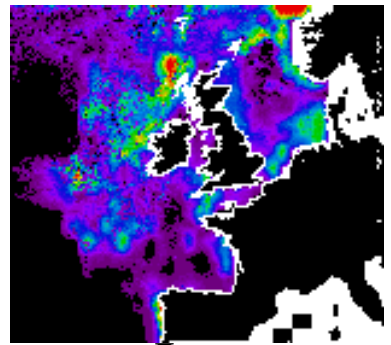
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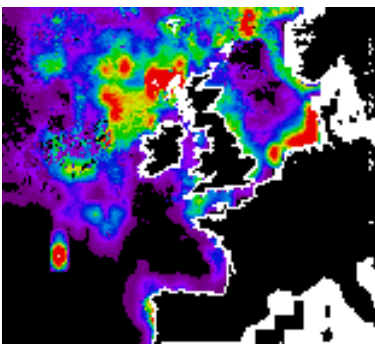
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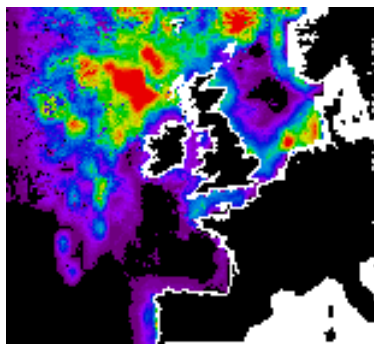
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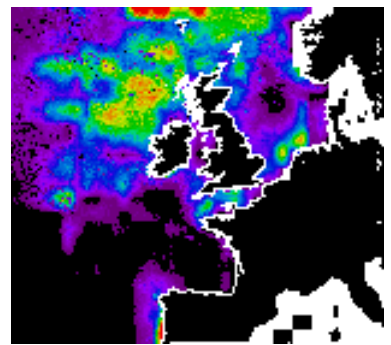
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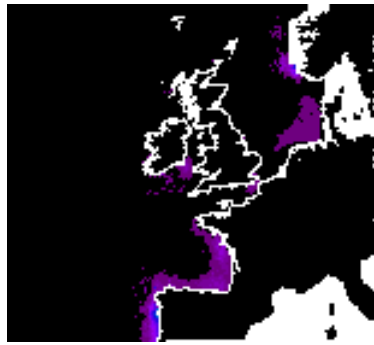
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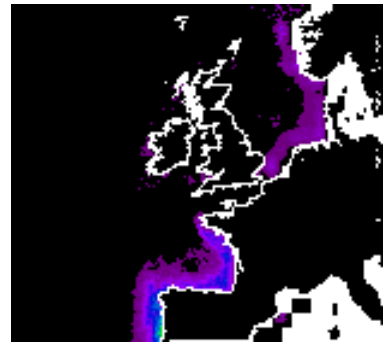
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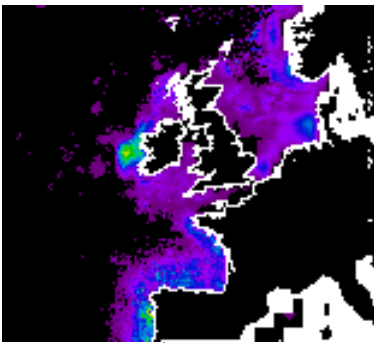
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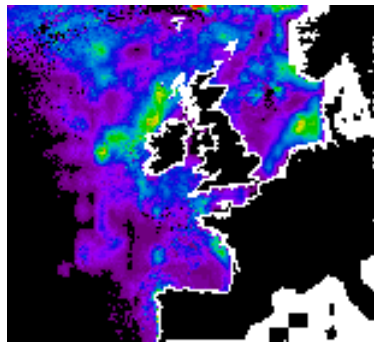
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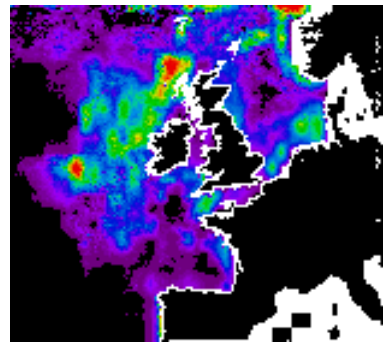
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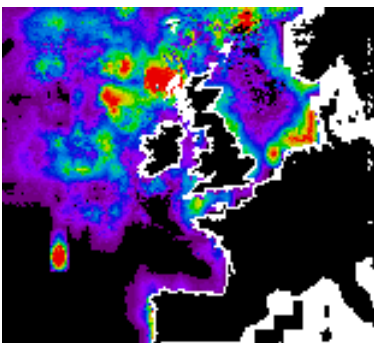
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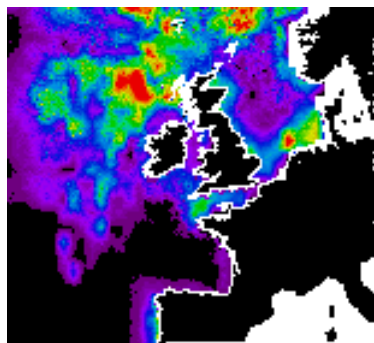
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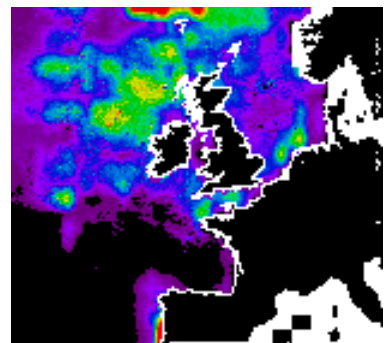
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