AN UNEXPLOITED SIZE SPECTRUM FOR THE SOUTHERN NORTH SEA

by Daniel Duplisea & Mark Bravington

Introduction

Biomass size spectra (BSS) are multispecies views of a system where biomass is partitioned by only individual organism body size without recourse to taxonomy. BSS models predict that the distribution of log biomass over log organism body size in the oceans should be linear with a slope (b), where $b < 0$:

$$\text{Log(biomass per unit area)} = c - b\ \text{Log(body weight)}$$

In the absence of exploitation, BSS models allow one to determine the biomass of organisms in any size class given that the biomass is known in another size class. We have used this property of biomass size spectra models to derive the theoretical biomass of commercially exploitable fish in the southern North Sea from phytoplankton biomass data.

Methods

An extensive data set was available for phytoplankton, zooplankton and fish size distributions as well as depth integrated chlorophyll concentrations in the southern North Sea for 1988. Hence all fitting and comparisons in this poster are for that year.

Phytoplankton

Zooplankton

Cod

Phytoplankton

Phytoplankton biomass at size data were available for bottle samples taken at about 1m depth. These surface densities were integrated throughout the depth of the water column to attain total biomass.

Good estimates of depth integrated chlorophyll biomass was available for 154 stations throughout the year. These values were average and converted to wet weight to obtain an annual average phytoplankton biomass of 724 g wet weight m^{-2}.

Zooplankton

A 70 mm diameter Hansen net with a mesh size of 300 µm was used to sample zooplankton in a vertical haul through the water column. Size spectra were constructed assuming that the net was 80% efficient as well as a size selective mesh efficiency ranging from 0.2 for the smallest to 0.7 for the largest throughout the sampled size range. Due to the large mesh size and gear bias we regard these data with a degree of suspicion.

Fish

Data collected in the English Groundfish survey were used. Survey data were corrected for size selectivity by taking standardised q at age values from ICES tuning fleet data and converting them to length and fitting a curve to these. Swept area density estimates were converted total density through multiplication of the VPA density/swept area density for cod which was then applied to all species.

Method

Total phytoplankton biomass was divided over 25 $\log_2$ weight classes ranging from -40 to -15 (bacteria to small zooplankton) and forced with a pre-set slope so that biomass in that range was equal to 724 g ww m^{-2}. This line was then extended into the fish size classes and compared to fish data from the EGFS.

Figure 1: the North Sea region with the study area highlighted in red.

Results

The theoretical slope of -0.22 underestimates the biomass of commercially exploitable fish in the southern North Sea by at least 1.4×10^6 t (Fig 2, 3, Table 1). An empirically realistic range of slopes of between -0.03 and -0.10 (Boudreau & Dickie 1992), indicated that fish biomasses at size should be greater, totalling 20.2×10^6 t and 1.97×10^6 t, respectively. We estimated total landings and discards in the southern North Sea demersal fisheries for 1988 were 1.14×10^6 t. It must be remembered that biomass deficits from the model are cumulative effects, hence one year's catch need not equal the model-data biomass deficit.

Flatter biomass slopes >-0.10 slopes appear to overestimate zooplankton biomass, however, this might be explained by gear inefficiency (Nichols & Thompson 1991). The phytoplankton and fish data are more reliable.

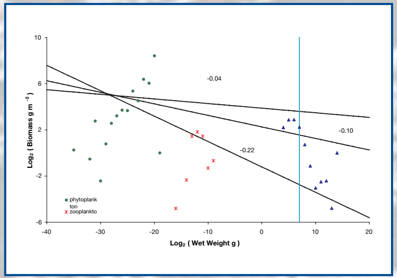

Figure 2: theoretical distributions of biomass in the southern North Sea under assumptions of three different slopes. Data are superimposed on theoretical predictions. The vertical blue line marks the approximate minimum body size where fish are commercially exploited (125 g).

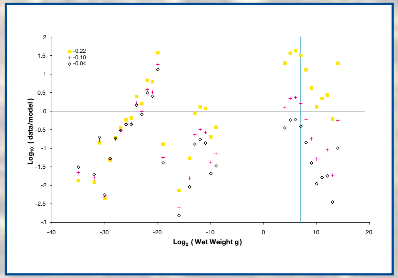

Figure 3: deviations of model predictions from data by body size for three slopes of a linear biomass size spectrum in the southern North Sea. The vertical blue line represents a minimum body size of commercial exploitation of demersal fishes (125 g).

fish weight (g)	slope =-0.22 (t)	slope =-0.10 (t)	slope =-0.04 (t)	landings and discards (t)
200	-8.77E+05	-3.43E+05	1.42E+06	
400	-2.92E+05	2.08E+05	1.94E+06	
1000	-6.70E+04	4.02E+05	2.11E+06	
2000	-5.50E+03	4.34E+05	2.11E+06	
3000	-1.83E+04	3.93E+05	2.04E+06	
6000	-2.28E+04	3.62E+05	1.99E+06	
12000	4.45E+03	3.64E+05	1.96E+06	
25000	-1.82E+05	1.54E+05	1.72E+06	
total	-1.46E+06	1.97E+06	1.53E+07	1.14E+06

Table 1: model biomass predictions minus data for commericial fishes in the southern North Sea as well as total landing and discards by ICES member countries in 1988. Total catch was calculated as the sum of landings in ICES areas IVc + IVb/2 (ICES 1992), assuming a 40% discard rate.

Conclusions

This exercise in determining theoretical fish biomass in the southern North Sea from phytoplankton biomass using a size spectrum approach gave reasonable answers when compared to data. The theoretical -0.22 slope was too steep to estimate even the present fish biomass which we know is heavily exploited. Our results suggest that slopes between -0.10 and -0.03 may be more appropriate.

Future Work

The present results are based on steady state assumptions. Future work will involve the examination of dynamic size spectra. By fitting fishery catch and natural primary productivity patterns as input, we hope to be able to predict size spectrum responses to changing exploitation.

References

Boudreau PR, Dickie LM (1992) Biomass spectra of aquatic ecosystems in relation to fisheries yield. Can J Fish Aquat Sci ***49***: 1528-1538

ICES (1992) Bulletin statistique des peches maritimes por 1988. ICES fisheries statistics ***73***: 116 pp

Moloney CL, Field JG (1985) Use of particle-size data to predict potential pelagic-fish yields of some southern African areas. S Afr J Mar Sci ***3***: 119-128

Nichols JH, Thompson AB (1991) Mesh selection of copepodite and nauplius stages of four calanoid copepod species. J Plank Res ***13***: 661-671

Sheldon RW, Sutcliffe WH, Jr., Paranjape MA (1977) Structure of pelagic food chain and relationship between plankton and fish production. J Fish Res Board Can ***34***: 2344-2353

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

http://www.cefas.co.uk

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science