A ROBUST OPTIMAL EXPLOITATION PATTERN OVER MODELS OF A SIZE-STRUCTURED COMMUNITY

by Daniel E. Duplisea and Mark V. Bravington

Context

Increasingly, there is a call for "ecosystem management". It is not clear, however, what ecosystem management is, but most agree that it should recognise multi-species interactions and ecological community effects. Fisheries are still species-directed and the necessity for single-species management will remain, however, we must meet the demands for community and ecosystem management advice.

Problem

Demands for single-species, multi-species and community management advice can force fisheries science to create increasingly complex models incorporating more and more components of the ecosystem. Increasing complexity, however, is not always a solution as it is accompanied by increasing parameterisation and increasing model uncertainty (Silvert 1982) (Figure 1). These are undesirable qualities in a predictive management model.

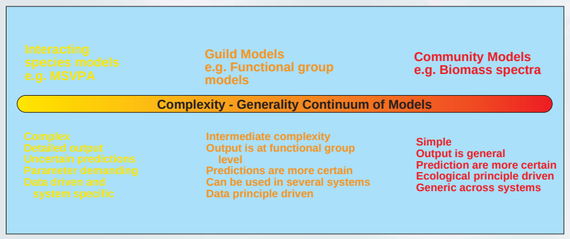

Figure 1

Approach

Essentially the only way out of this complexity problem is to construct several models of different conception over which certain commonalities exist that enable the transfer of management scenarios between them. The goal is then to seek robust patterns that transcend model structure and which can be transferred into management advice (Duplisea and Bravington 1999).

We have constructed two models of a size-structured fish community which are fundamentally different in their conception. In these models we seek an optimal fishing effort which maximises sustainable yield.

References

Duplisea, D. E. and M.V. Bravington. 1999. Harvesting a size-structured ecosystem. ICES CM /**Z:01**

Magnússon, K. G. 1995. An overview of the multispecies VPA — theory and applications. Rev. Fish Biol. Fish. **5**: 195-212.

Pope, J. G. and B. J. Knights. 1982. Comparisons of length distributions of combined catches of all demersal fishes in surveys in the North Sea and Faroe Bank. Can. Spec. Pub. Fish. Aquat. Sci **59:** 116-118

Silvert, W. 1982. Top-down modelling in multispecies fisheries. Can. Spec. Publ. Fish. Aquat. Sci. **59**: 24-27.

Silvert, W. and T. Platt. 1981. Dynamic energy flow model of the particle size distributions in pelagic ecosystems. In: W. C. Kerfoot (ed) Evolution and ecology of zooplankton communities. University Press of New England, Hanover, NH. p 754-763

Models:

Two multi-species/community-based models were developed for hypothetical fish communities (Table 1):

(1) a length-cohort model with ten different species, similar to Multi-species Virtual Population Analysis (MSVPA) (Magnússon 1995). A baseline community was chosen with a maximum-size distribution similar to the North Sea and a mixture of species types: not unlike a natural diverse fish community.

(2) a size-based energy flow model based on biomass size-spectra theory (Silvert and Platt 1981). Species are not considered in this model, just organisms of different sizes. The model was parameterised with simple relationships from the size-spectra literature.

Optimal yield for both of these models was determined as the four point fishing mortality at size pattern which maximised total value-yield in the system at equilibrium (hence sustainable yield).

Characteristics of the two models used to search for model predictions

Model	Model characteristics
length-cohort model	• 10 species • species are defined by r-K continuum classification and maximum body size • all species eat each other, including cannibalism. • large individuals eat only smaller individuals • allometric growth • growth is independent of food consumption • stock recruitment relationship • a predation model where mass is not conserved
biomass spectrum model	• total community biomass in a size interval • large individuals eat only smaller individuals • allometric growth • growth depends on food consumption • constant base production • mass is conserved

Table 1

Results

Both models suggested that an increase in fishing mortality with body-size was the strategy that maximised sustainable yield (Figures 2 and 3). This answers Pope's question on what the optimal harvesting strategy should be in a size-structured ecosystem (Pope and Knights 1982). The resulting value yield was dome shaped, indicating that most of the yield came from small and intermediate sized fish. This pattern generally results from allometric predation and growth that is included in both models. That is, large organisms eat smaller organisms and specific growth rate is higher in smaller organisms. This implies that yield to the fishery is maximised if the large predators are kept at low levels (even though they are valuable) and therefore the surplus small and fast and growing prey are available for the fishery to harvest. This harvesting strategy is contingent upon the community composition.

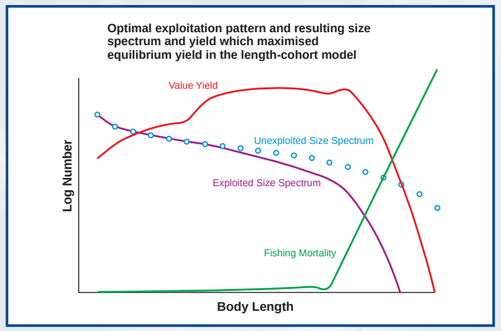

Figure 2

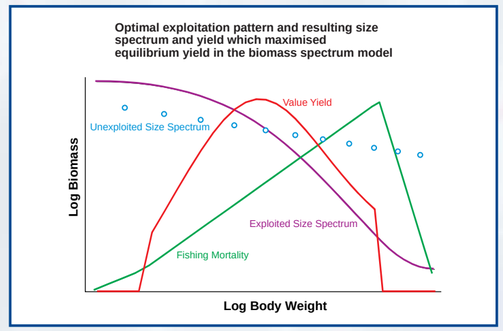

Figure 3

General points

- It is possible to find a consistent exploitation pattern which transcends model structure for at least one management goal (maximum sustainable yield).
- A variety of management goals could be examined with extensions of these models.
- Both single species and community level management advice could be derived from these models.
- A size-based conception of the ecosystem and its components allowed a consistent parameterisation and operational fishing management strategy (F at size).
- Interpretation and concensus for management advice is still required where the models indicate different fishing strategies.
- Work is underway to add further types of models to the pool.

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK http://www.cefas.co.uk
E-mail: d.duplisea@cefas.co.uk ; m.v.bravington@cefas.co.uk

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science