BRIDGING THE GAP: FLEETS, FISHERIES AND THE ECOSYSTEM APPROACH

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ABSTRACT

Current ICES advice for fish stocks is based on single species stock assessments. As such they involve giving advice on individual species, across a large area, based on very detailed data. In contrast the requirements of the ecosystem approach involve advice on a much wider range of species and a much finer spatial scale, for which there is typically much more limited data. Assessment and management of mixed-species, multi-fleet fisheries represents an intermediate situation between single species fisheries management and the application of a full ecosystem approach, in terms of their complexity, data needs and spatial scale. As a result, recent developments in approaches to give advice on a fishery basis, rather than a stock basis, offer a way to bridge the gap between existing single species approaches and the needs of the ecosystem approach. Here we describe these approaches and discuss their possible extensions and applications to the ecosystem approach to fisheries management.

INTRODUCTION

Most European demersal fisheries are mixed in nature, in that they involve the capture of a mix of different species at the same time. This can lead to problems in management if the stocks caught together have different conservation needs. Recently, this has been the case for the demersal fisheries in the North Sea, where the cod stock has fallen to a very low level, leading to advice to close the fishery, while the stock of haddock, which to a large extent is caught together with cod, has reached its highest biomass in thirty years (ICES, 2006b). Until recently, the main management measure for these stocks has been single species TACs. If these are set in isolation, with no consideration of the status of the other stocks caught in the same fishery, this may lead to the problem that vessels soon exhaust the TAC for cod but continue fishing for haddock and thus still catch cod even though it cannot be landed legally. As a result the cod TAC does not achieve its intended conservation benefit. Indeed, Bannister (2004) identified the mixed-species nature of the fishery, along with its international dimension, as the two main factors contributing to the cod decline, despite all advice having been consistently intended to reduce F.

This element of mixed fisheries has led to interest in ways to account for these technical interactions in giving fisheries management advice. The key aspect of these approaches is that they incorporate more information on what the fishers and their vessels are doing, rather than just relying on the biological information available from single species stock assessments. The initial, short-term requirement comes from the Memorandum of Understanding between ICES and the European Commission:
"For each sea area ICES shall define groups of stocks within which ICES shall ensure close quantitative consistency between the advice given for each stock.

This should be considered a first step in the development of fisheries-based advice. ICES will be invited to explore during the course of the agreement how advice may be further developed to advice on changes in fishing practices for defined fishing fleets."

This requirement for "close quantitative consistency" can be interpreted as simply giving TAC advice which takes into account the extent to which the different species are caught together, and implies a similar level of fishing effort for each fleet concerned. However, we consider that the potential benefits offered by the explicit inclusion of fleet and fishery information in the advisory process are much greater than just meeting the short-term requirement for more consistent TAC advice. In this paper we outline recent developments in fleet and fishery-based approaches to providing advice, and discuss the potential for these approaches to be used in a broader management context, particularly the need to give advice based on a much wider range of ecosystem components than just the main commercial fish species.

TERMINOLOGY

Central to any studies of fishing activity and its impact is the classification of vessels and their activity into relatively homogeneous subsets. Here we follow ICES (2003) in using the following terminology:

• A "fleet" is as a physical group of vessels sharing similar characteristics in terms of technical features and/or major activity (e.g. the Dutch beam trawler fleet < 300 hp, regardless of which species or species groups they are targeting).

• A "fishery" is a group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Dutch flatfish-directed beam trawl fishery in the North Sea).

• A "métier" is a homogeneous Subdivision of a fishery by vessel type (e.g. the Dutch flatfish-directed beam trawl fishery by vessels < 300 hp in the North Sea).

Note that under this terminology a vessel will belong to a specific fleet, based on the vessel's physical and geographical characteristics. Each voyage, or trip, made by a fishing vessel will be allocated to a specific fishery based on attributes of that trip. The term 'métier' is used to represent the intersection of fleet and fishery; hence the activity of a given fleet can be described by how many trips or days it allocates to each of its métiers.

Perhaps the key point of these classifications is the separation between the vessels, which are classified into fleets, and their activity, which is classified into different fisheries. From this it is clear that vessels are not fixed in their activity but can respond to management measures in different ways.

THE FCUBE METHOD

The fleet and fisheries approach is currently being developed and implemented for providing mixed-fisheries advice into the "Fleet and Fisheries Forecast" method, also called Fcube (Ulrich et al., 2006; ICES, 2006a, 2007). Fcube was selected within an ICES workshop as the most suitable candidate approach as replacement of the MTAC method (Vinther et al., 2005). MTAC represented an initial attempt to use fleet catch information to give TAC advice for mixed fisheries. However this was unsuccessful for a number of reasons, not least the way that catch data are used to parameterise the model makes no distinction between the fleets and their activity.

The conceptual basis of the Fcube approach is that a fleet can exploit a number of different fisheries during the year, hence the partial fishing mortality it exerts on a given species can be estimated from the amount of effort allocated to a given fishery multiplied by the catchability of that species in that fishery to that fleet, summed across all fisheries exploited during the year. Although it is conceptually straightforward (Figure 1), this approach offers a way to incorporate more sophisticated models of fishing activity and thus draw on the previous research work in this area.

Initial exploratory applications of Fcube have involved hindcast testing to predict fleet catches by species based on different assumptions about total effort, for example assuming that fleets either fish until the first TAC is exhausted, or fish until all TACs are exhausted, or fish according to the TAC of their most valuable species (ICES, 2007). Such applications can be used to illustrate the extent to which the single species TACs are inconsistent with each other in terms of the effort they imply, and can thus give an indication of the extent of non-compliance with catch regulations

(Figure 2). Trial runs could also be performed considering complex regulation constraints on one type of fishery only. For example we demonstrated how to evaluate some benefits of reducing the effort of large mesh size towed gears only, thus mimicking the current days at sea system implemented in the North Sea under the cod recovery plan (ICES, 2006b). Furthermore, this method is being tested within larger scale simulations for Management Strategies Evaluation. Hamon et al. (2007) have shown that the cod recovery, meant to be achievable within ten years when considered in isolation, would not be achieved if cod fisheries were driven by high haddock TAC and overquota catches were assumed, thus confirming Bannister (2004) hypotheses.

Methodological development is ongoing in order to release an operational version of the method for direct use in mixed-fisheries advice. This will take the form of a R package compatible with the FLR simulation framework (Fisheries Library in R, Kell et al, 2007; http://flr-project.org).

BRIDGING THE GAP; THE BROADER APPLICATIONS OF FLEET AND FISHERY-BASED APPROACHES.

While the short-term application for Fcube is in relation to providing advice for mixed-species fisheries in such a way that it allows consistency between species, the implications of incorporating fleet and fishery approaches into the advisory system are rather wider than this. For the large majority of ICES stocks, advice has traditionally been required in the form of single species TACs. The implicit assumption when such TACs are used as a management measure is that once the TAC is exhausted fishing on the stock will stop. In reality, fisheries are rarely that simple, hence this assumption is frequently not met and TACs may not limit fishing pressure. The basic assumption of the Fcube approach is that fleets can allocate their fishing effort across a range of different fisheries. This is an explicit generalisation of the implicit assumption behind the single species TAC. It implies that instead of only one incentive (i.e. the single species quota), fleets can respond to a range of different incentives, and instead of just one action (i.e. stop fishing) a wide range of responses to the different incentives are possible. This allows for a much more flexible and realistic framework on which to base management advice. In particular, by focussing on fisheries and fleets, rather than just stocks, the approach recognises that fisheries can have a wider range of impacts than just on the major target species. As a result the approach would also provide a framework for advice on impacts on non-target species and other components of the ecosystem. In this respect, the incorporation of fleet and fishery information provides a bridge between the traditional single species advice and the ecosystem approach to fisheries management.

It is instructive to view fisheries and their constituent parts as a continuum, ranging from a simple, single species, single gear fishery where the only concern is for the target species, right through to complex mixed-species, multi-gear fisheries where there is concern for the impact of fishing on non-target species and other components of the ecosystem, as well as on the main commercial species. The data and methods used to give scientific advice, and the form of advice itself, will change depending on the nature of the fishery and which aspects of it the advice is required on. This can be represented in terms of a series of axes describing the nature of the fishery (single to multiple gears; single to multiple species); the object of the advice (single species through to whole ecosystem); the tools used to give advice (from single species stock

assessments through to ecosystem indicators), and the form of the advice (from prescriptive through to more adaptive and indicative).

To illustrate both the concept of the continuum of fisheries and approaches, and the possible application of fleet and fishery-based approaches it is useful to describe a number of hypothetical cases that lie at different points along these axes.

1, Single species, single gear fishery, TAC advice

Management advice for this situation has typically been provided using a stock assessment and forecast, with advice given in a prescriptive form, i.e. "*if you set this TAC, the result will be this F and this SSB*".

2, A limited number of species and gears, TAC advice

As with case 1, management advice will be based mainly on stock assessments and forecasts, but there may also be a need to take into account the extent to which the different species are caught together in which case additional information on catches by fleet will also be required. As with 1, the advice is likely to be prescriptive in form.

In this case, a tool such as Fcube could be used to show the mis-match between different species-specific TACs, and could then be used to propose a set of TACs that were more consistent across species in terms of the fleet effort they implied.

3, A larger number of species and gears; Effort and/or TAC advice

In a more complex mixed-fishery situation like this, it is less likely that stock assessment will be available of sufficient precision for all of the stocks of interest. It thus becomes more critical to reflect the activity of the vessels in the management advice, rather than just basing it on the fish stocks. In particular it becomes important that the fishing activity is reflected in well defined fisheries which reflect both the spatial aspect of fishing activity and the extent to which species are caught together. In this situation, fleets are unlikely to allocate the effort according to the abundance and distribution of particular species, but instead will switch between different fisheries at different times of year.

As advice may need to be framed in terms of catches or effort or both, there is less scope for advice to be prescriptive in form. This is particularly true for effort as there is rarely a well-defined relationship between fishing effort and fishing mortality, hence the desired level of F cannot be achieved by simply specifying a total effort. Instead, effort advice may need to be given in a more adaptive form, e.g. by specifying a fixed percentage reduction each year until a specific target is met.

With a tool like Fcube which accounts for the fleet and fishery structure of fishing activity, annual advice for this case study might be formulated something like this:

Under this set of assumptions about fleet effort, catchability and allocation of effort between fisheries in year Y *:*
- *The estimated catches of each species by each fleet will be…*

- *This will lead to estimated total catches of each species of…*
- *The implied fishing mortalities on the major stocks will be…*
- *The resulting SSBs of the major stocks will be…*
- *The changes indicated for the minor stocks are…*

To reflect the complexity of this situation, it will be necessary to present information for a wide range of different species, fleets and fisheries. This reduces the emphasis on just one or two stock assessment parameters as the basis of management as there will also be a wide range of other indicators to inform management. Hence the basis of the advice is intermediate between stock assessments and ecosystem indicators, being a range of indicators of commercial fish stocks that include stock assessment results. Using a similar fleet-and fisheries based approach, Ulrich et al. (2001, 2002) estimated equilibrium consequences of alternative effort-based regulations for the 23 international fleets present in the English Channel, engaging in 55 different fisheries and catching a mixture of 53 fish and invertebrate stocks. Stocks were dealt with using a combination of age-based and surplus production models, using for each stock the best level of knowledge available.

4, A large number of species and gear; ecosystem-based management.

We here interpret ecosystem based management as management of fishing activity based on information on a wide range of components of the ecosystem and not just the target fish species. Such management is perhaps likely to involve a complex of different management measures, including closed areas, partially closed areas and effort management amongst others.

Again, the classification of fishing activity is of key importance here. Given that problems with ecosystem impacts of fishing are often associated with the use of a specific gear in a particular area (Daan, 2005), the definitions of 'fisheries' would need to reflect these impacts on the non target species as well as the commercial fish species. This adds to the information requirements of such a system, as while information on landings of the commercial species should be available from landings declarations, corresponding information will not be available for species which are discarded or even impacted on the seabed. This in turn implies that it may be necessary to use information on these impacts in a more qualitative way.

If we assume that a full ecosystem approach to management is not implemented until a few years under a system more like case 3, then, based on experience with that approach we may have the advantage of being able to model how fleets respond to management measures by changing their activity. As such the hypothetical advice could look something like this:

Under this set of management measures in year Y.
- *The (modelled) allocation of effort between fisheries is indicated to be …*
- *This will have these implications for the main target species…*
- *These implications for the secondary (assessed) species…*
- *These implications for non-commercial species…*
- *These implications for selected benthos (some fisheries only)…*
- *And these implications for the fleets…*

In this case the implications for the various species of interest would most likely be expressed as estimated relative changes (and associated uncertainties) on indicator scales rather than in absolute biomass terms. By nature, advice will need to be both multi-annual and adaptive. It will not be possible to say "*do this and this will be the result*"; it will be more like: "*keeping taking these actions, adjusting as necessary, until some or all of these indicators reach these reference points.*"

DISCUSSION

The case studies above are intended to be hypothetical, and particularly in the latter examples are rather speculative, but they do serve to illustrate how single species and ecosystem approaches are opposite ends of a spectrum, and that the explicit representation of fishing activity is a key factor in moving between the two extremes. The example cases are limited to considering only annual advice, whereas the state of the art in single species advice involves harvest control rules and management strategy evaluation approaches. A key scientific challenge in this respect will be to incorporate fleet- and fishery-based approaches into a management strategy evaluation framework to explore how such a system might work in a mixed-species fishery at least. Some work is ongoing in that direction (Hamon et al., 2007; Ulrich et al., 2007), and Fcube should be an integrated part of the simulation frame.

With any fleet and fishery based approach it will not be sufficient to present only information on the species concerned; by nature it will also be essential to provide information on the fleets and fisheries involved. It may useful to consider this as providing fleet and fishery assessments alongside the stock assessments. At its most basic, a fleet assessment might involve a simple description of the number and size of vessels in each fleet in each year, in order to provide an indication of potential changes in capacity and fishing power. There would also be scope for developing economic models of entry and exit to the fleet which might have application in management strategy evaluations.

Fishery assessments would need to describe the activity of the different fleets. As a minimum this would involve summarising the total amount of effort expended by each fleet in each year, and also summarising how this was partitioned between the different fisheries available to that fleet. This would lead naturally into the use of fleet dynamics models used in both a retrospective context (to quantify the response of fleets to past management measures) and a predictive one. To link fishing activity with the stock information would require some quantification of the relative catchability of each species within each métier. As with the stock information, the ease with which this can be readily estimated will vary considerably from the routinely assessed species right through to non-target species and benthos. This is an area where research on gear selectivity and other aspects of fishing gear technology could prove effective.

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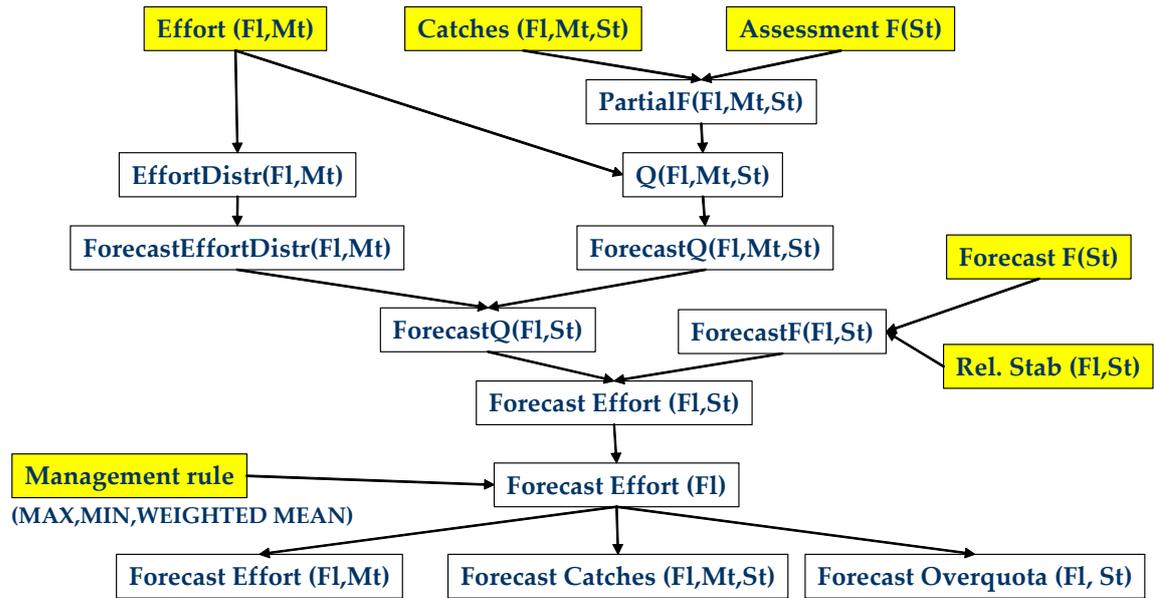
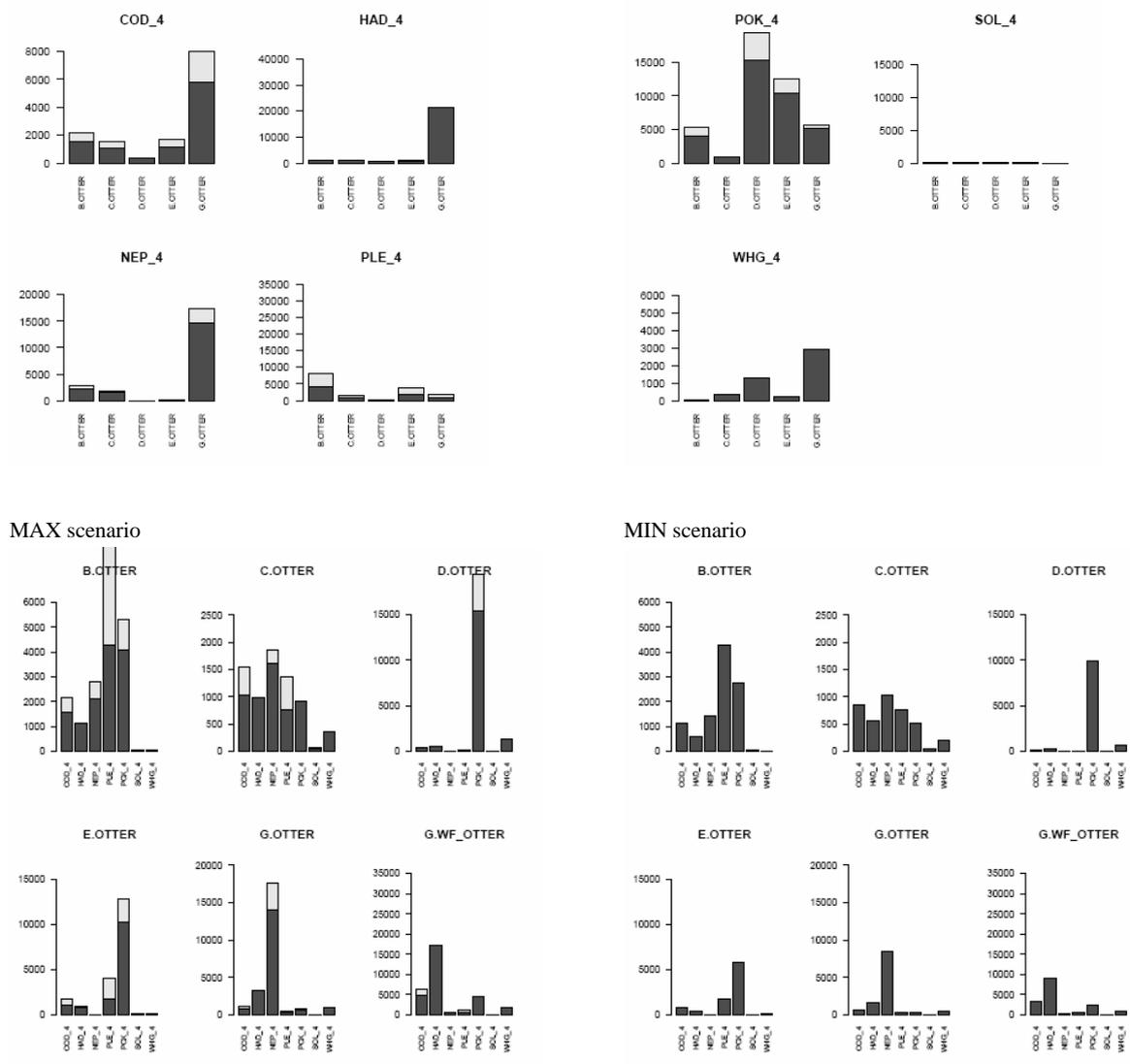**Figure 1.** Fcube conceptual flowchart. Yellow boxes : inputs.

Figure 2. Illustration of some Fcube outputs (from ICES, 2007). Top: Total predicted 2005 landings (black) and overquota catches (grey) by North Sea stock under the MAX scenario. Bottom: Comparison of effort scenarios, North Sea trawlers data. Landings (black) and overquota catches (grey) by fleet and stock under alternative assumption of fleet behaviour. Cap letter represent an anonymous country code. MAX scenario: fleets fishing until last quota is exhausted. MIN scenario: fleets fishing until first quota exhausted. (See ICES, 2007 for explanation).