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Practical issues in choosing a framework for resource assessment and management of Mediterranean and Black Sea fisheries

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Abstract

Local context and practical constraints are important in deciding on assessment procedures for Mediterranean and Black Sea fisheries, and in formulating management measures that reflect the resource life history, fishery configuration and availability of data. A brief review of existing methods is provided, and a recommendation that practical approaches need to focus on developing the indicators and reference points appropriate for fisheries management decisions. In both the Black Sea and Mediterranean Sea proper, experience suggests environmental and ecosystem concerns must be given a high priority in the assessment process.

Keywords: Stock assessment; Mediterranean fisheries; Fishery indicators; Resource management methods.

Introduction

A debate on the appropriate approaches to stock assessment in the Mediterranean and Black Seas has been ongoing within the General Fishery Commission for the Mediterranean (GFCM) for the last 20 years or so, which has surely a wider interest to those concerned with Mediterranean fisheries, and the debate provides the motivation for this paper. The issue came to a head in the 26th session of GFCM, which requested its Scientific Advisory Committee (SAC), *'to review existing stock/fisheries assessment methods, highlighting data needs, outputs expected, pros and cons, and their suitability to Mediterranean stocks and fisheries. On the results of the above analysis, SAC was requested to define a set of most appropriate assessment methods which should results in the establishment of a harmonised assessment methodology, agreed by scientists of Member, and which is a prerequisite for a rational decision-making process.'*

Following this request, OLIVER (2002) prepared a working document on methods of assessing Mediterranean fisheries (Annex 8 of the report of the Sub-Committee on Stock Assessment, 2002). This was circulated and discussed within a stock assessment meeting in Barcelona, May 2002. Given the generally incomplete data on catch effort and size/age composition of the catch, the Oliver report suggested that length cohort analysis (LCA) is the only standard methodology potentially applicable at the regional level. This conclusion was contested by LEMBO *et al.* (2002), where scientists from the central and eastern Mediterranean observed that other methodologies are also appropriate. They observed that time series for cohort analysis proper (e.g., LASSEN & MEDLEY 2001) are rarely available in the Mediterranean, and that the debate should focus around methods that can employ available data. Methodologies such as those in MUNRO (1980); SPARRE ET AL. (1989); GAYANILO *et al.* (1996) have proved useful for species where time series are scarce. This discussion therefore has highlighted the lack of consensus to date in Mediterranean fisheries science on a standard assessment methodology. The last-cited paper concluded that the results from Length Cohort Analysis 'must be handled with caution', considering the few years of data available. The authors noted that the use of 'pseudocohorts' in methods assuming constant M for all ages, 'drastically conditioned the results'. These authors also remarked on the need to address discrepancies between estimates from VPA and those from trawl and echo-surveys (ULLTANG, 1996; PENNINGTON & STRØMME, 1997). If a constant natural mortality rate is used in the analysis, VPA may lead to biased estimates of the numbers of recruits and hence may bias the Stock Recruit Relationships (SRRs) derived from them (HILDEN, 1988).

The approach taken in this paper is that the assessment methods selected should be usable with data currently available or soon to become available, and should provide output appropriate to the management approach used by the GFCM and the Black Sea Commission. The type of stock assessment analyses carried out in these seas have usually been seriously constrained by the data collected, and dominated by approaches in the first category of the list below. The range of scenarios has usually resembled one or other of the following:

1) Occasional or 'unique' samplings over a short period of stock size/biomass, size-frequency of landings, growth and mortality estimates, and (more recently) similar short period studies of ecosystem structure/food web linkages. These provide static pictures of the current situation and require an 'equilibrium assumption' if they are to be applied over other time periods.
2) Models fitted have predominantly been yield/recruit, egg/recruit with few production models, and analyses mainly by pseudocohorts or size frequency methods (e.g., JONES, 1984) and relatively few VPA or cohort analyses based on multi-year data series.
3) A few studies have estimated fleet capacity, or monitored fishing effort or the number of boats actively fishing by category/gear.
4) Studies on selectivity, bycatch, and degree of discarding have recently begun, but indirect estimates of mortality due to fishing on discards or escapees are not available.
5) Regular port-based coverage of the quantities of landings is not always implemented. Due to the reluctance of fishermen to see the high value catch handled during measurement, size compositions may not be available, nor age sampling for otoliths carried out in many fisheries. Few artisanal gears (often tak-

ing the more valuable species) are sampled regularly.

6) Estimates of the number of days spent at sea by a representative sample of each vessel category (from port interviews or commercial log books) are available for some fisheries, but time and area of fishing are rarely confirmed by at-sea surveillance or on-board observers.

7) Annual trawl surveys of the biomass on the grounds (e.g. MEDITS; GRUND) have been carried out regularly in some areas, and acoustic surveys or egg and larval surveys are implemented in a few areas for pelagic resources.

PAST ASSESSMENTS IN THE MEDITERRANEAN AND BLACK SEAS

Past approaches to assessment in the Mediterranean

Until a decade ago, most Mediterranean stock assessments probably fell into categories 1) or 2) of the above list with occasional activities under 3) – 5) and 7). Items number 1) to 7) are not necessarily either/or options, but the cost of data gathering and the numbers of skilled manpower needed, generally increases from 1) to 7). Areas of the world where methodologies 4) -7) are commonly implemented (e.g. the North Atlantic) are still confined to some western Mediterranean and Black Sea sub-areas, countries, resources, and fisheries. Such methods should be used where appropriate, and should not be reinvented. Now, size or age-structured analyses must often be based on research survey catches, and require innovative approaches to provide indicators of the fishing pressure being exerted.

Considerable progress has been made in the last decade in the northern Mediterranean in implementing annual trawl and acoustic surveys. There are also problems in identifying stock units, and matching the origin of commercial catches to the corresponding data from the survey biomass estimates. Thus, although LLEONART (2002) provides a useful review of the range of methodologies available globally to be applied to Mediterranean stock assessment, the practical constraints in applying some of the more sophisticated methods are evident. The software for Extended Survivor Analysis (XSA) is available from the Lowestoft program (DARBY & FLATMAN, 1994) and has been used to assess well-documented single species fisheries in Spanish waters and the Adriatic, but the data to apply such approaches seems the exception rather than the rule. The conclusion is that while methodologies dependent on time series of size/age in catch and biomass should be applied where data are available, the immediate difficulty is how to assess fisheries where catch sampling is not carried out in a statistically reliable fashion, and where size and age structure of catches is not available. In some cases, yield per recruit and pseudocohort analytical approaches such as VIT have been applied, and despite the problems these are likely to face if environment or productivity changes, pseudocohort approaches may have to be applied to many single species assessments (OLIVER, 2002).

A reliance on sampling by research vessel is inevitable if biological samples are not regularly available commercially. This makes methods such as VPA, which rely on catch samples as input, problematic! It also raises the key question: what information can be extracted from MEDITS data without catch sampling being necessary? North Atlantic methodologies where port sampling is a norm are not of great assistance here, and priority should be given to developing methods appropriate to the Mediterranean and Black Sea contexts.

A parallel approach is to use time series analyses to extract more information from series of biological and environmental data (e.g., LLORET *et al.*, 2000; STERGIOU *et al.*, 1997), and time series of environmental or economic information should also be incorporated into the assessment approach. If sufficient confidence exists as to the statistical properties of the underlying parameters, Bayesian approaches may of course be attempted. The opposite assumption to Bayesian analysis is to consider that the biological and economic system generating the statistics is within a 'black box', since the detailed linkages between system components are largely unknown.

To avoid duplication, I paraphrase the comments of LEMBO *et al.*, (2002) on assessment approaches:

Prior to the MEDITS surveys (BERTRAND *et al.*, 2002), catch trends were used to analyse the status of fisheries (e.g. LLEONART, 1999) or for short term forecasts of harvests (STERGIOU *et al.*, 1997; LLORET *et al.*, 2000). In the north-western Mediterranean, Length Cohort Analysis (LCA) assuming equilibrium conditions is widely applied, and requires a knowledge of size distributions of catches (the pseudocohort approach), the gear selectivity, and estimates of the biological parameters (e.g. JONES, 1984; LLEONART, 1993; PRODANOV & MIKHAILOV 2003). The VIT package based on LCA and Y/R (LLEONART & SALAT, 1997; FRANQUESA & LLEONART, eds., 2001) is a development of this approach.

Surplus production models were popular in the 1970's and 80's (e.g. GHARBI, 1985) and avoid problems due to a lack of biological data and catch age structure. Their main defects at that time were unreliable estimates of total catches and unsuitable effort units. However, they share with other time series methods a lack of adequate contrast in the data, given that most stocks are now fully or over-exploited; hence fitting models that depend on a wide range of independent data, and also assume environmental stability (CADDY 1993), is problematical. Nonetheless, production modelling using the total mortality rate appears promising, as do composite production models (see below).

It seems that we need to retest the non-equilibrium production modelling packages now available (PUNT & HILBORN, 1996), and reconsider whether production modelling would work better within the Operational Unit (OU) framework established recently by the GFCM for collecting data by key fleet segments. Fine mesh trawl surveys can be used to directly estimate the pre-recruited portion of the stock, and this combined with parental stock estimates to give stock recruitment relationships (SRRs). So far, few such SR relationships are available. The Daily Egg Production Method (e.g. CASAVOLA *et al.*, 1998) has also been often used to evaluate spawning stock biomass which can also be directly estimated for small pelagics by hydro-acoustical surveys. Experimental trawl data are also suitable for some length or age-based assessments. LEMBO *et al.* (2002) also noted that composite production models (MUNRO, 1980; CADDY & GARCIA, 1982) using simultaneous information from ecologically similar subareas exploited at different rates, are useful where long data series on catch and effort are not available. GARCIA (1983) used this approach to assess the state of exploitation in sub-regions off the Spanish coast. The status of fisheries for *Merluccius merluccius and Mullus barbatus* off the western coast of Italy and eastern Corsica was recently assessed using MEDITS survey data (ABELLA *et al.*, 1999). They combined a Composite Production Model with the CADDY & CSIRKE (1983) variant of the Surplus Production Model which uses total mortality rate Z as an index of effort, and catch per unit effort as an abundance index. This approach allowed the status of each sub-area to be determined relative to the overall mortality rate. From an estimate of overall Z, the position of the fishery on the curve of species productivity relative to the Maximum Biological Production (Z_{MBP}) was deduced. As noted by DIE & CADDY (1997) this reference point corresponds to a slightly lower exploitation rate than the Maximum Sustainable Yield, is relatively stable and easy to calculate, and is a fairly moderate Target Reference Point.

What other methodologies are there available? One answer is that agreed to for the Black Sea; namely to monitor key species which are indicators of specific habitats/ecosystems by regular surveys, and display annual values of these indicators together in a traffic light display system. The other priority would be to use these indicators in fishery control laws to help make decisions on stock recovery plans for depleted resources.

Past approaches to assessment in the Black Sea

Suggestions have been made for Black Sea fisheries that stock assessment methods should be standardized. However, a wide range of hypotheses have been offered to account for ecosystem changes, including overfishing, nutrient enrichment, and exotic pelagic predators. As such a standard assessment approach risks misidentifying causal factors. Given this uncertainty, the output from several different modelling and assessment approaches should be compared, and a reliance on indicator trends rather than model outputs has emerged as a practical approach (CADDY 2005); using the Traffic Light methodology to contrast trends in different time series of information (CADDY *et al.* 2004).

The Black Sea is an enclosed sea subject to land influences with a lower biodiversity than the Mediterranean proper. Age- and size-structured data were collected for key species until the 1980's, and cohort analyses and other age-structured approaches routinely employed (see PRODANOV *et al.*, 1997). Some regular surveys still persist and new ones have been initiated by Turkey, but the impression is that not all time series of survey data dating from the 1960's and 70's still continue, probably for financial reasons. This is relevant, because in the absence of continuous surveys, methodologies such as production modelling or VPA/cohort analysis requiring recent time series, are no longer possible. If this is the case, it seems urgent to restore previous survey time series using the same sampling gear and procedures to the extent possible, otherwise methodologies relying on time series of size/age data will be inapplicable.

Dramatic changes in environments, fleets, and in some cases, the privatization of formerly nationalized fleets, have made it difficult to compare recent Black Sea data with the earlier well-documented period, or to make assumptions of stable productivity. This problem is also faced for Mediterranean fisheries analyses, and in both seas the assumption of ecological stability may be in-appropriate. Environmental change, both natural and anthropogenic, drives ecosystem productivity and modifies faunal compositions of semi-enclosed seas (e.g. CADDY, 1993; ZAITSEV, 1993). A traffic light approach (CADDY, 2002) for the Black Sea illustrated that major changes in environmental conditions and faunal introductions in recent decades were added to uncontrolled effort in the pelagic fishery and resulted in changes to ecosystem productivity. In particular, there was a serious drop in landings during the main *Mnemiopsis* leydei bloom in 1989-92, and apparently linked changes in the trends of species landings occurred (CADDY, 2002; MUTLU *et al.* 1994). Apparent recoveries of landings of some species over the last five years may either reflect steady increases in effort, or real stock improvements, and resolving this dilemma urgently requires assessment of fishing mortalities over time. Attempts to restart the assessment process following a period of political change in the fisheries sector, and biological/environmental changes, is described in OZTURK & KARAKULAK (2003). In contrast, a long-term decline in landings occurred for migratory pelagics, which for chub mackerel dropped steadily to close to zero over recent years. This comparison suggests that different ecological stresses have applied to resident and migratory pelagic species, which will need to be considered in stock assessments.

Serious changes in fishing pressure, the ecosystem and the environment of the Black Sea have been evident, with impacts differing by species. A major question is how do we build environmental inputs and biodiversity change into our resource analysis and advisory functions?

PRODANOV *et al.* (1997) showed that in the 1970's and 80's, methodologies of single species assessment had arrived at a high level prior to the environmental and socio-economic changes which disrupted some time series of age or size-specific data. Politico-economic events also affected assessment work and regular surveys, and led to changes in national fleet dominance. For former socialist countries, the switch to private ownership of fishing vessels may have led to changes in sampling procedures. All of these events may have compromised continuity of sampling in ways that need to be better defined. An attempt to restart a cooperative Black Sea assessment process under the aegis of the Black Sea Environmental Commission decided to begin with a list of indicators needed for assessment purposes (see CADDY *et al.*, 2004), but it remains to be established if the data series needed for these are still available.

Excellent reviews of earlier stock assessments (e.g. IVANOV AND BEVERTON, 1985; PRODANOV *et al.*, 1997) provided material that let us explore different approaches to monitoring stocks and define reference point values. At the same time, a study of catch trends (CADDY *et al.*, 2004) showed that basing analyses on earlier data and assuming stability in the Black Sea ecosystem is not a safe strategy (e.g. ZAITSEV, 1993; KIDEYS, 1994). Environmental changes and signals will also need to be monitored.

If recent fisheries time series are unavailable, an immediate priority would be to repeat earlier mortality, yield or fecundity per recruit analyses with current data, to determine what changes in stock status have occurred subsequently. DASKALOV, (1999) provided a new approach which appears promising if the data are available to apply generalized additive models. Similar models have been applied in well documented fisheries in the western Mediterranean (e.g. GOÑI, *et al.* 1999).

Status of fisheries in FAO Area 39 judging from landing trends

Recent temporal changes in combined landings for the main Mediterranean and Black Sea resources of FAO Statistical Area 37 are shown by CADDY & SURETTE (2005) in traffic light format, based on time series from the FAO database. Obviously the time series do not correspond to individual stocks, and for some species, landings came from both the Black Sea and Mediterranean. It was clear that the peak production years were in the past for most species, and in some cases, a 'red' colouration has persisted for the last six years or so, strongly suggesting the stock must be 'depleted' and in need of recovery measures. The implication of the traffic light display for stock assessment is that recent 'red' data probably corresponds to 'fully or over-exploited' categories.

A wide range of exploitation rates are unlikely in recent data, since most fisheries of the Mediterranean and Black Sea are likely to be close to full exploitation or over-exploited. This will make the fitting of yield models to new data problematic. Other criteria will have to be used to determine optima: both economic, in terms of productivity, and progressively from an ecosystem and biodiversity perspective.

The availability of data restricts the methodologies that can be used

Given the limited finances and manpower constraints of many member countries of GFCM, the stock assessment methodologies commonly employed in the North Atlantic cannot be routinely employed for lack of appropriate time series of catch, effort and/or biomass data by species. One may hope that European Commission Regulation No 1581/2004, which provides a minimum standard for collection of data on fishing vessels, will be more widely applied but in the Mediterranean, enforcement of such standards on small fishing vessels poses a practical dilemma for understaffed data collection services.

Similar problems have been faced by ICCAT (ICCAT, 2004) in collecting data on large pelagic catches in the Mediterranean for use in cohort analyses. Multi-country catches are not always available or broken down by size. It seems unlikely that dramatic improvements will occur in sampling and statistics collection for the whole range of fishing vessels and species captured, and in any case, it will be almost a decade before methodologies based on new time series data can be used in time series analyses. It seems to me that the following approaches are most likely to be fruitful over the short term:

- methodologies using short-term data, but with sensitivity analysis
- searching for existing historical indicator series that can provide indirect measures of resource health and past effort exerted, and using these in a control rule.
- repeating past analyses using up to date data and comparing results.
- developing methods based on overall mortality rate and biomass that can be derived from the MEDITS or other RV survey data series.
- relying on those extensive multidisciplinary, environmental, economic and multispecies time series that exist, expressed in traffic light format.

Approaches to analytical methods

Most trawl fisheries here, (including those using 40 mm stretched mesh) either target small species, or larger juvenile finfish prior to maturity. This is a fundamental difference from the Atlantic, where, at least when BEVERTON & HOLT (1957) produced their theory of yield/recruit, fisheries were mainly aimed at larger and older age groups for which the assumption of constant natural mortality was reasonable. This is not the case for most fine mesh Mediterranean demersal fisheries (CADDY 1996). LEMBO *et al.* (2002) commented that considering the small size at first capture, it is likely that heavily-exploited juveniles suffer higher natural mortality rates than older individuals, due to both density-dependent processes and predation pressure (For hake see ABELLA *et al.*, 1997; 2005a; red mullet VOLIANI *et al.*, 1998). This issue has been discussed at length in earlier GFCM meetings, and it is clear that yield/recruit or spawner/recruit methodologies that do not take into account the likely higher natural death rate of age 0 + to at least 1 + fish, but assume 'constant natural mortality' through life will give biased results (ABELLA *et al.*, 1997). Unlike the various Beverton-Holt yield/recruit programmes, the Thompson-Bell procedure for yield or fecundity/recruit calculation (RICKER, 1975), easily accommodates a declining vector of natural mortality, or other vectors that change with age such as fecundity and spawning success.

Unfortunately, the higher species diversity of Mediterranean fisheries makes a repetition of the MSVPA experiments to determine 'M's–at-age' in the North Sea problematic. One approach to obtaining indicative vectors of natural mortality values suggested by CADDY (1991), rested on finding that $M_t = a + b/t$, where a, b are constants and t = age. This function provided a good fit to the rare data sets then available globally for M-at-age of marine fishes, and fitted well MSVPA data from the North Atlantic. ABELLA *et al.* (1997) provide several approaches to fitting this model. This involves iterative fitting of the above model for successive size intervals, under the assumption that the number of survivors from an estimated mean lifetime fecundity is reduced to one male and one female by the time the mean reproductive age is reached. An alternative approach, given life history stages where the risk of death is the same, will last longer if M declines with age. This approach assumes that the product: $M.\Delta t$ is constant for successively longer (Δt yr) life history stages (CADDY, 1996). This is an alternative approach to modelling early life history risk of death given a rapid decline in M-at-age to a plateau for older organisms. This gnomonic time-division approach for successive life history stages was used by ROYER *et al.* (2002) for squids, RAMÍREZ-RODRÍGUEZ & ARREGUÍN-SÁNCHEZ (2003) for shrimps and MARTÍNEZ-AGUILAR *et al.* (2005) for sardines, and these Mexican studies appear to confirm that this is a useful approach to modelling M-at-age for many species.

Most Mediterranean demersal fisheries can best be defined as fisheries for juveniles, and this should be a significant factor in deciding how to parameterise the assessment approach. If we assess the impact of changes in effort or mesh size on a fishery for juveniles without considering the higher natural mortality rates that apply, the long-term gains associated with a mesh-size increase will be overestimated. Sensitivity analysis to test hypotheses for the vector of natural mortality rates at age is critical for drawing conclusions from yield-per-recruit computations on the current status of the fishery and in assessing the optimal combination of F and mean size at first capture. CADDY & ABELLA (1999) used a length-based VPA to compare the size composition from fine mesh surveys with the simultaneous size composition of catches in adjacent ports, and showed that a steeply declining rate of natural mortality for juvenile hake was the vector best able to reconcile commercial catch and trawl sampling data from the same grounds in a pseudo-cohort analysis.

Studies with higher natural mortality rates for juveniles suggest that although fecundity per recruit would be increased somewhat with an increased minimum size, this will not increase yield per recruit markedly. Modelling life histories with a natural mortality vector that declines sharply in the first 2 years of life, makes it clear that the first priority is to conserve spawners, which in a heavily exploited stock become 'rare events'. Active measures are needed to avoid fisheries targeting mature fish, and not to deplete the spawning stock causing recruitment overfishing!

If the assumption of a constant risk of natural mortality from 0+ ages onwards predicts over-optimistic benefits from mesh size increases, these approaches promote targeting of older age groups, and underestimate the biological and economic importance of conserving older spawners in refugia which support juvenile fisheries (CADDY & SEIJO, 2002).

Priorities for establishing indicators and reference points

Following the UN Fish Stock Agreement in 1995, attention was directed to the need to define Limit reference Points (LRPs), and to establish indicator series to monitor when the fishery approaches these danger points. The last meeting of the Black Sea project aimed at setting up a system of biologically-based indicators for each component of the Black Sea ecosystem (lagoons, demersal habitats, pelagic habitats, threatened species, etc). The Traffic Light approach allowed their display and preliminary diagnosis as a first step to the use of assessment methods or modelling (CADDY, 1999).

The first global approach to defining reference points was to establish targets for management, and assumed that reference points must be derived from fitted mathematical models (e.g. MSY and others – see CADDY & MAHON, 1995). Since the FAO Code and UN Fish Stock Agreement in 1995, limit reference points have been given priority, with the understanding that they will be used in fishery control rules. More recent applications (e.g. GILBERT *et al.*, 2000; SEIJO & CADDY, 2000) suggested that reference points do not necessarily come from fitting models, as long as the conditions where the fishery begins to suffer from overfishing can be specified directly from time series displays of indicators. In fact, prematurely formulated models may introduce misconceptions as to the causative factors operating. Supporting this perspective, TRENKEL & ROCHET (2003) and ROCHET & TRENKEL (2003) noted that most multispecies indicators to date have been based on theoretical considerations. They found that 'empirical' population indicators such as mean length in the catch, the pelagic/demersal index (DE LEIVA MORENO *et al.*, 2000; CADDY & GARIBALDI, 2000), the overall exploitation rate, or the proportions of non-commercial species and piscivorous fish in the commercial catch, were statistically more reliable than indicators based on food web modelling. A similar conclusion was reached by JENNINGS *et al.* (2002) from stable-isotope analysis of food web components and by PATTERSON

(1992) for small pelagics. Mean trophic level and the pelagic/demersal ratio (De DE LEIVA MORENO *et al.* 2000), have theoretical disadvantages as indicators in that they could be indicators both of increased nutrient inputs and bottom-up effects, as well as overfishing of top predators.

Limit reference points and indicators at the ecosystem level

The following decisions were made on indicators at the workshop on demersal resources in the Black Sea and Azov Sea, of the Black Sea Commission; 15-17 April 2003, Sile, Istanbul, Turkey.

1) It would be better for the Commission to recommend a focus on collection of research indicators for a limited number of species and population characteristics, while allowing the possibility to revise the number of indicators subsequently if needed.
2) Some 'keynote species' should be decided on as a focus for maximum effort of cooperative studies.
3) Country responsibilities for studies on keynote species are not confined to those countries currently taking the major catch – other countries should contribute data.

Displaying multiple indicators – the Traffic Light approach

We need a procedure for first examining and hence displaying multiple indicators on environment, recruitment, biomass and if possible predator abundance (KOELLER *et al.*, 2000), and the Traffic Light approach has already been adopted for a similar overview role by the SAC subcommittee on Marine Environment and Ecosystems (SCMEE, 2005). This approach allows a large number of indicators to be displayed together in a 'model-free' environment where preconceptions as to causative factors are set aside, and observations that some time series show similarities or differences are allowed to support one or other conclusion as to possible causative factors. Indicators in a Traffic Light array may measure population characteristics such as biomass or mortality directly or indirectly, and can be extended to include spatial data (e.g. on indicator could be the extent of the stock area surveyed annually containing 75% of the stock or recruits), or could use environmental or economic data. Judgements made from a knowledge of life histories, or from previous events in the same fishery may be incorporated in deciding for example, on the cut-off points between adjacent colours in the TL chart. Such an approach has been referred to as a Traffic Light monitoring methodology (CADDY, 1999; HALLIDAY *et al.*, 2001). The 'Working Group on Biological and Economic Indicators for the Demersal Fishery in the Adriatic Sea' (May 2005) demonstrated the utility of grouping indicators and displaying them separately for three operational units (OUs) using a TL scheme: 20 biological and 25 socio-economic indicators were assembled, with colour cut-off points at the 33rd and 66th percentiles of the observed indicator ranges, and illustrated the declining productivity of Adriatic demersal fisheries.

Is a 'Mediterranean' approach to assessment advice needed?

The classic aims of stock assessment are to advise fishing management on the likely response of 'unit populations of a single exploitable resource' to changes in fishing pressure; to provide options to managers on safe exploitation rates, and to advise on the associated technical measures.

Many 'assessments' at GFCM have been extrapolations from estimates of growth and mortality of individual species, mainly derived from samples collected over short time periods. They have been applied in yield per recruit or egg per recruit models that resemble the 'constant parameter approaches' of BEVERTON & HOLT (1957). Fundamental assumptions have often been (erroneously) that the fishery is for mature fish, and that adult M values derived from generalizations on the relationship between M for adult fish and their growth rate, as measured elsewhere in the world (PAULY, 1980) should be applied.

The role of spatial factors: nurseries and refugia

Stock units are often assumed to correspond to local statistical areas and closed populations, but an explicit approach to juvenile fisheries management should recognize the need for seasonal or permanent closures of nursery areas and spawning refugia within MPAs, and should make full use of GIS technologies (see CADDY 1998; COPEMED, 2000) to map biologically important 'critical habitats'. Juvenile stages of important demersal species often pass their early life history in a restricted area, often but not always inshore, and reviving the older Mediterranean life history models in quantitative form (Fig. 1), and using information on seasonal and life history changes, are likely to be critical to the success of local management measures. The nursery areas of hake and other demersal species in the Adriatic and central Mediterranean have been identified, and offer the opportunity for applying seasonal and spatial control measures to selectively harvest specific age classes. Figure 2 is probably still a valid conceptual scheme, and emphasizes the importance of integrating biological information with assessment work. Nursery areas of different species have been identified and their spatial dimension estimated (e.g. LEMBO *et al.*, 1998). The importance of closing these areas for juvenile protection has been highlighted, but there has been less understanding of the need to protect spawning stocks in areas where juvenile fisheries are predominant.

Figure 2 places this issue in a population dynamics framework with spatial considerations included, and suggests that a 'bottleneck' on juvenile production may exist: based on the limited extent, ecosystem integrity, and degree of protection afforded to nursery areas.

Similar considerations apply to the area of spawner aggregation where such areas exist.

Given a general lack of information on stock boundaries, the assumption is usually that local fleets exploit local resources, but better information is needed on fleet distributions to verify this, and local information will be more easily obtained by local management units. Within each subarea, the local distribution of resources, habitats and effort can be stocked in a GIS system, and MPAs or other seasonal closures will be more effectively located.

Perhaps the term 'stock assessment' is unduly restrictive for the wider range of advice managers need on fishery resources and their status. Classically, a stock assessment has been the study of population structure, dynamics, and past exploitation of a single population and its reaction to the dominant influence of fishing pressure. It seems useful to broaden the scope of 'stock assessment' by stressing that more is

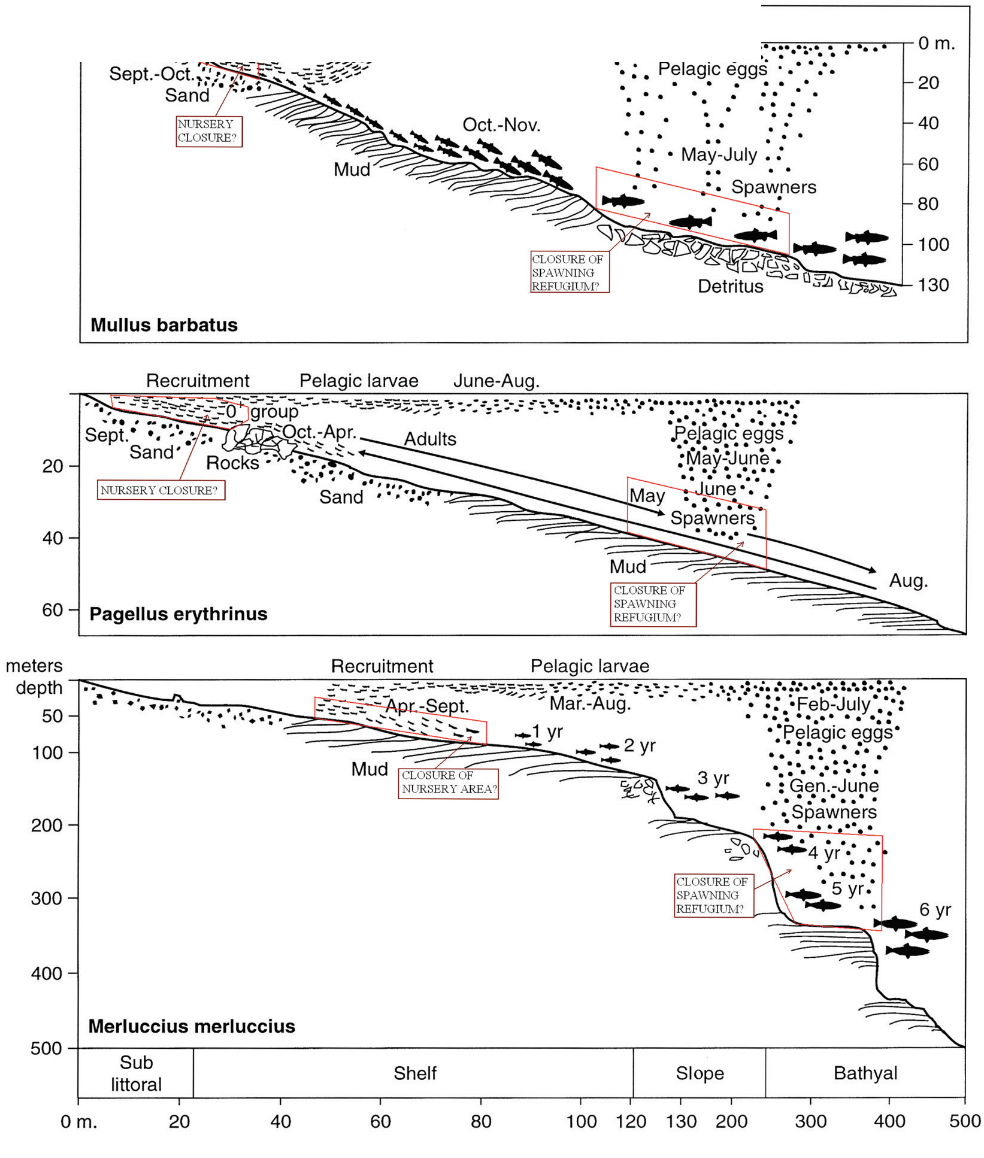


Fig. 1: Illustrating early knowledge of the seasonal and life history distributions of Mediterranean resources (From Doumenge 1966). In marked areas are those suitable for spawning and nursery closures.

needed for managing a resource than simply an analysis of the dynamics of single populations, or to estimate the fishery's current position in relation to a limit reference point. We also need to know how the ecosystem is reacting to exploitation and environmental change. Especially, but not exclusively in the Black Sea area, environmental/ecosystem considerations have had an overriding impact on ecosystem pro-

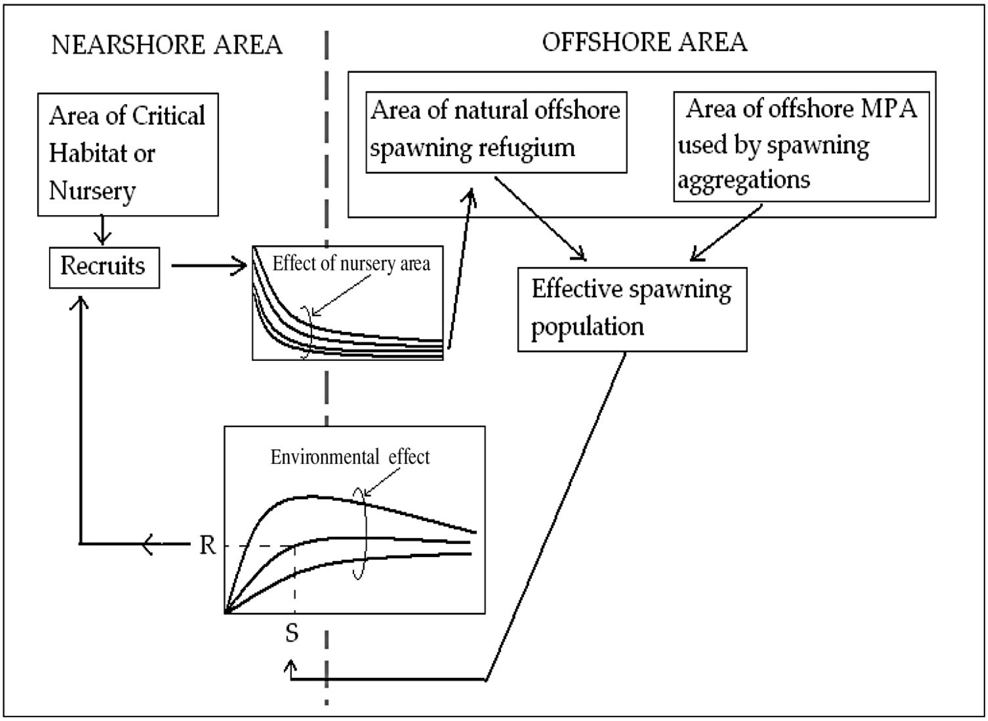


Fig. 2: Schematic for an approach to modelling life histories of demersal resources incorporating closed areas to fishing.

ductivity. Especially for high unit value resources such as many Mediterranean species, bioeconomic analyses will be needed for management decisions.

An independent opinion: should assessments be repeated annually?

The independent group of experts (GFCM, 2003) urged GFCM not to *'fall into the trap of providing yearly assessment'*, since experience suggests these vary considerably more than do the stock sizes themselves, thus creating a problem of credibility for the SAC process, and absorbing the work time of the few experts available. Since quota control is not applied, it is not evident that the main control mechanism (i.e. effort control and technical measures) will need to be adjusted annually. Therefore in deciding on methods of analysis and provision of advice, we should consider what management measures are envisaged, and what types of advice they require. Direct control of fishing effort is the approach adopted by SAC, and will require specific assessment methodologies – what should these be?

Other issues addressed by the group of experts were new management approaches such as MPAs, and the recognition of spawning refugia, and nurseries. In addition to more detailed studies of selectivity, estimates of indirect mortalities on juveniles from trawling, and their implications for management should be studied. The danger of increasing discarding through focussing heavily on regulating minimum size at landing was emphasized, as well as the importance of studying the survival of juvenile fish passing through cod-end meshes.

Two issues need discussion between scientists:

1) Given informational uncertainties, what information management needs to implement precautionary control laws?
2) What are the criteria for deciding which species need stock recovery measures and how these should be implemented?

Making better use of trawl survey data

A key scientific question at this point, is what methods can be applied to extract the most information from survey data alone, (e.g. MEDITS surveys), for assessment purposes?

The Independent Group of Experts (GFCM, 2003) also made reference to the need to use trawl survey data to identify species assemblages, and a full coverage of the Mediterranean waters by a MEDITS survey in 2005 was recommended. Priority was placed on monitoring abundance of adults and juveniles by regular surveys, and on integrating survey results with statistical data from commercial operations, to provide essential information for assessments of stocks, and multispecies or bioeconomic modelling. Monitoring the number of fishing operations, and/or the number of vessels with access to the fishing grounds, is essential for monitoring the effects of fishing on ecosystem productivity. While MEDITS data will not lead directly to vectors of fishing mortality, it provides estimates of biomass and annual recruitment, and indirectly, can give total mortality rates (Z's) from (e.g.) catch curve analysis of aged survey samples by key species. From these data, the productivity of a stock $P = B_{av}.Z$; using the average biomass (B_{av}) from surveys can be monitored.

Two approaches to fitting a dynamic production model approach to survey (e.g. MEDITS data) where no information on annual catches is available.

One basis for dynamic production modelling (e.g. HILBORN & WALTERS, 1992; DEFEO & CADDY, 2001) has been the equation:

$$B(t+1) = B(t) + r^*B(t)^*[1 - B(t)/k)] - C(t) \quad ...1)$$

Where r and k are parameters of the production model, and C(t) is the total catch in weight taken from biomass B(t)'. The problem is how to fit this equation where only biomass (Bt) in year t is available, which is essentially the situation for many Mediterranean demersal trawl fisheries where there are surveys, but no time series of size or age sampling from commercial catches exists in the survey area. This makes it difficult to fit some variant of VPA or ADAPT in order to estimate the fishing mortality rate, F.

In these circumstances, it may still be possible to estimate the overall mortality Z(t) for a species from the age/size composition of the survey catch, and this approach was used by ABELLA *et al.* (2005b) in the total mortality-yield approach to production modelling. Approximate values of M may also be available, which should correspond to that applying at the mean age of the stock. Two approaches may then be used to fit the above model using the SOLVER routine of EXCEL, if time series of biomass and overall mortality are available. This will depend on finding an approximation for C(t) - the yield in year t:

a) C(t) = B(t)*[F(t)/(Z(t)]*[1-exp – (Z(t)]
b) C(t) = Bav(t)*[Z(t)-M]

— where Bav is the mean biomass during the year.

PAULIK & BAYCLIFF (1967) compared these 2 apparently different formulations, and b) corresponds to their approximation to the yield equation:

ΔY_i = $Fbar_i$*Nbari*$wbar_i$*Δt_i .....2), - where X in the successive symbols (Xbar) represent means for fishing mortality, numbers, and individual weight in the catch, with Δt_i in this case corresponding to one year.

Approximation b) was suggested as the justification for the Thompson-Bell approach to yield modelling, and becomes more accurate if used for shorter time intervals than one year. The last-cited authors noted that equation a), although apparently more elaborate, assumes a strict exponential decline which is unlikely, but that the two models 'give practically the same result' if the product (gi-Mi-Fi)*Δti - is small, where gi is the instantaneous growth rate of the population.

— Obviously the 'exponential method' assumes that the trawl biomass estimate corresponds to the initial biomass at the start of the year, while the alternative formulation assumes that the trawl biomass corresponds to the mean biomass throughout the year. In both approximations a) and b) above, we are effectively estimating F(t) by subtracting an estimate of M from the annual Z for the stock. This is assumed to correspond to the mean Z value obtained by analysing the survey catch size or age composition. The potential errors here could be due to changes in F(t) and M(t) with age. It is obvious that the estimates of Z_t made by catch curve analysis for example (which depend on numbers at age in past years), will be influenced by values of Z_t in previous years, but will not reflect the current Z_t, for reasons given by RICKER (1958). Nonetheless, we could use this approach to obtain a rough estimate of B(MSY) = k/2 under the Schaefer assumption, or obtain an indicator for deviation from MSY conditions from 2*B_t/k. The data sets available do not present many other alternatives to this very approximate method, which does provide at least a way of monitoring the stock situation and obtaining indicators of mortality and biomass that may be useful to management.

Special issues

From almost 2 decades of experience as technical secretary of GFCM, the author noted that three common errors were frequently made in Mediterranean stock assessments and resulted in biased conclusions. All came about by extrapolating from methodological assumptions made in fisheries for mature fish, to Mediterranean fine mesh trawl fisheries for juveniles:

1) von Bertalanffy fits of growth curves should not be used in yield modelling which show large negative values of t_0; if this result is obtained, the curvature of growth trajectory in the first few years of life at a time is underestimated, at a time when the largest numerical proportion of the population is being captured for many Mediterranean species. The wrong von Bertalanffy parameters of course will affect the value of M resulting after entering them into the PAULY (1980) equation. This in turn, biases yield calculations based on this M value as input. This fitting error for the growth curve

and its consequences may result from giving too high a weighting to the more numerous older age groups relative to the points for the first 2-3 years of life when the majority of a cohort is captured. For some demersal species it may also be due to a slowing of growth as young fish move offshore into colder, less productive waters. Forcing the curve to pass close to zero would provide some more realistic parameter values for stock assessment. For juvenile fisheries, seasonal monitoring of growth on nursery areas would be preferable in providing realistic data points for the first few years of life.

2) Assuming the natural mortality rate is constant and low for the first few years of life will of course bias the conclusions from yield/recruit, fecundity/recruit, and VPA or pseudocohort calculations (see earlier).
3) The trawl selection curve may not be asymptotic. Although this may be true for larger mesh trawls and species where juveniles and adults are mixed on the trawling grounds, fine mesh selectivity and availability may differ: i.e., adult fish may not be available to the gear when trawling inshore (e.g. on nursery grounds), or larger fish may evade fine mesh trawls which project a pressure wave.

Different approaches to stock assessment and resource advice

Four main sources of information are available; special samplings and field experiments (e.g. from closed areas), research vessel surveys, commercial samples and their analysis, and time series of other data (economic, environmental, biological). These provide indicators that feed into three main research approaches:

— empirical approaches, or those using statistical analysis to identify possible causalities.
— assessment methods based on age/size structure (analytical methods) or catch/effort/mortality rates (production models).
— conceptual models such as ECOPATH which build on preconceptions such as the interelationships between ecosystem components.

If methodologies such as VPA, Y/R and Egg/R analyses are used to predict the effect of a fishery, at the very least a sensitivity analysis should be carried out with a vector of M values similar to that resulting from the ICES MSVPA experiment (SPARHOLT, 1990), or other sources mentioned in CADDY (1991). Also relevant is the 'Cyprus Effect' (GARCIA & DEMETROPOULOS, 1986) which has been confirmed by seasonal closures introduced in Italian waters. This showed that removing fishing pressure from inshore grounds at the time or soon after settlement of juveniles to a benthic life, dramatically improved recruitment and yield, well in excess of predicted changes from constant parameter yield/recruit predictions.

The flow chart in Figure 3 suggests three main approaches to the formulation of resource advice, and useful ancillary information will result from comparing these three approaches. All three may generate indicators and LRPs that can be examined by management to establish priorities for management action. These indicators and their RPs could be built into a Fisheries Control Rule which will suggest what management measures are appropriate based on the value of an indicator relative to its LRP (see later).

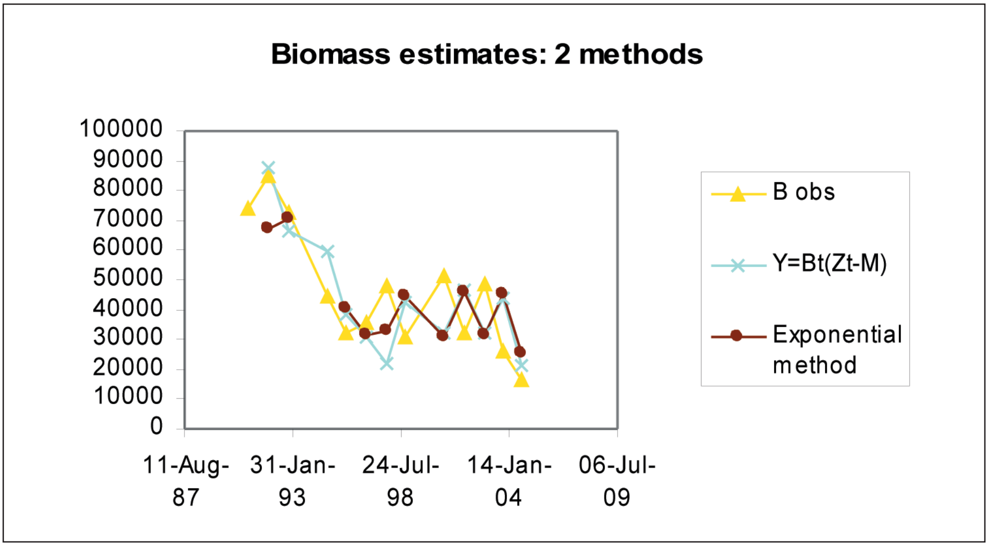


Fig. 3: Simulation of observed and estimated biomasses, using two formulations for Yield, C(t).

MONITORING AND ASSESSING MULTISPECIES RESOURCES

In 2003, a meeting of independent experts (GFCM, 2003) recommended that SAC should focus on multispecies /multidisciplinary approaches: a conclusion that came also from the Reykjavik Conference of FAO on ecosystem approaches. It was noted that the SCSA had only produced single species assessments to date, 'while recognizing the essentially multispecies nature of Mediterranean fisheries'. The group suggested that a selected interdisciplinary group 'through a single integrated advisory process...should use multispecies reference points and management strategies compliant with an ecosystem approach to fisheries'. It is not very clear, however, what these approaches should be.

Biodiversity issues

Figure 4 is based on the pooled 20 yr series of GRUND data, and suggests that the demersal fauna off Livorno has remained highly diverse despite high fishing intensity, but obeys certain regularities such as a log-linear decline in densities on the ground for ranked species. The diversity greatly exceeds that for the north Atlantic, and closely resembles the highly diverse faunas described by LAVETT SMITH (1975) and others for coral reefs. There seems some potential to follow up here by comparing ranked species lists at different time intervals to establish anthropogenic and other impacts on the ichthyofauna.

Multi-species assessments

Most fishery assessment theory has been developed around single-species fisheries, but most Mediterranean fisheries are multispecies with upward of 100 species in some trawl fisheries. Single species theory applied to multispecies fisheries will be 'completely ineffective' (ACCADIA *et al.*, 2006). GFCM has specifically subscribed to multispecies & ecosystem approaches,

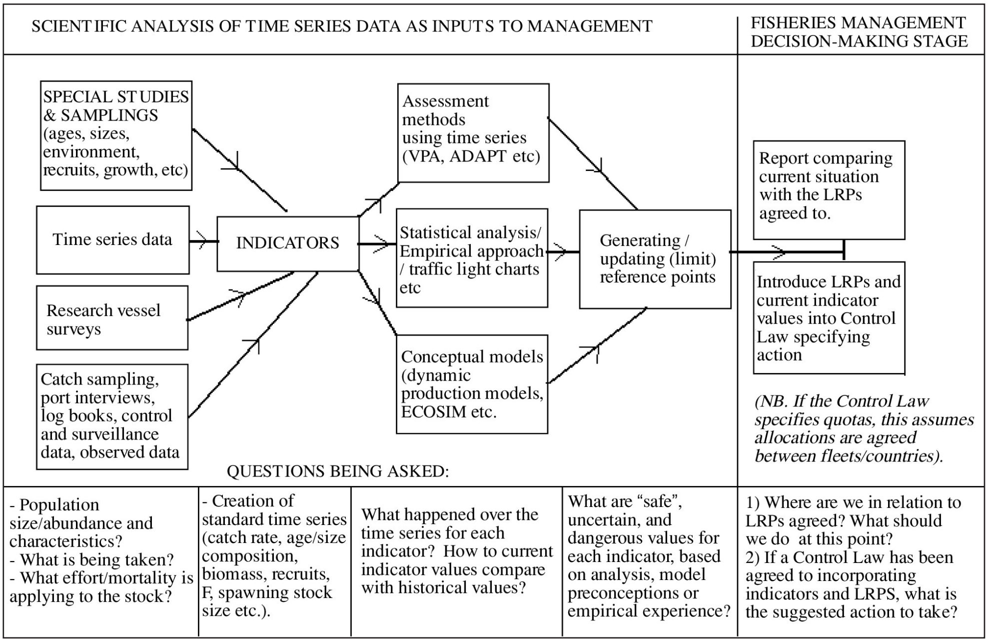


Fig. 4: Some alternative trajectories for scientific data-gathering, analysis, and advice to fisheries management.

and this poses a practical and theoretical challenge to assessment work in the region.

An example of the use of trophic models for generating indicators was the major effort put into developing the MSVPA model for the North Sea. This demonstrated the high rates of piscivory on small fish, but also revealed that diets and ration sizes are highly variable with season and age, and extensive sampling is required to fit multispecies models in a continually changing ecological situation often characterised by regime shifts.

The question of whether top down or bottom up processes predominate is an important one, and field observations and experimental studies along the lines of the ICES MSVPA experiment would be productive, if expensive and difficult to duplicate. Following the paradigm suggested by PAULY *et al.* (1998), DASKALOV (2002) suggested that in the Black Sea a trophic cascade has been in operation driven by top-down processes, and GUCU (2002) supports the role of fishing as determining ecological change. Others have pointed to bottom-up environmental effects as predominant; driven by the effect of an excess of nutrient inputs on the planktonic regime which resulted in a rain of detritus to the sea floor and consequent hypoxia of shelf waters (ZAITSEV 1993). Surely, the causes of this dramatic change are multiple, such that premature modelling may not reveal causations.

The emphasis on Ecosystem-based Fisheries Management (EBFM) suggested at the 2001 Reykjavik Conference on ‘Responsible Fisheries in the Marine Ecosystem’ (SINCLAIR & VALDIMARSSON,

2003) initiated a debate on the appropriate assessment methodologies to support ecosystem management. Apart from theoretical studies, it is fair to say that not much progress has been made to date anywhere in applying multispecies theory to management, and much theory has developed from preconceptions as to what limits populations rather than on data analysis. Due to a lack of information, recourse is often made to the precautionary approach. Theoretical studies of food webs to measure ecosystem overfishing and generate reference points have been proposed, and Ecopath and Ecosim provide useful background, though CHRISTENSEN & WALTERS (2001) caution against too literal interpretation of the results from a management perspective.

Evidently we also need to look more closely at the data itself, and tie ecosystem changes to changes in fleet and effort time series. The tendency to move first to trophic models is surprising when the basic analysis of catch trends still remains to be done (using methods such as cluster analysis for example), and it is not always clear that trophic limitations are dominant for depleted stocks or are always top-down in action. For example, a study presented at the 7th SCSA meeting showed a positive correlation between small and large pelagic catches in the Mediteranean, suggesting that consumption of pelagic fish and squids by predatory fish may be equal to, or exceed commercial landings, and that a bottom-up control mechanism predominates. If so, this would suggest maintaining high biomasses of small pelagic fish as food for economically more valuable top predators. In the Black Sea, the hypothesis that a high biomass of pelagic fish is needed to control the biomass of jelly predators also deserves some consideration. The possibility exists that where large predatory demersals have been heavily depleted, food shortage may be less of a problem than climatic change or ecosystem degradation.

As illustrated by an Ecopath model of the Black Sea (CHRISTENSEN & CADDY, 1993), it is possible to use this approach to draw 'snapshots' of the ecosystem at different points in time, recognizing that ecological changes caused by adding an exotic species, *Mnemiopsis leydei,* drastically changed energy flow patterns through the pelagic food chain. This last study also hypothesized that adding a (then hypothetical) predator, *Beroe spp* to feed on *M. leydei* would be beneficial. This forecast was perhaps confirmed when *Beroe* was subsequently introduced to the Black Sea, and perhaps as a result, *M. leydei* populations dropped to more 'normal' levels. The key point is that ecosystem change may occur for reasons other than just trophic limitation (e.g. pollution, nutrient runoff, habitat loss, exotic species addition), and that the actual components of the ecosystem may change, and not just the abundance of native species. In fact, several Black Sea species adapted to low nutrient conditions have disappeared or become uncommon and been replaced by exotics.

Indicators based directly on incoming data from surveys can be useful, even before the intervention of a model. Given that models assume that the factors underlying the fisheries outputs are understood, which is not always the case, empirical approaches which generate statistically valid trends from incoming data are becoming recognized as a more realistic alternative. Thus, the impact of fishing on size frequencies caught has been reported on by POPE & KNIGHTS (1982) and more recently by SHIN *et al.* (2005). Monitoring fisheries impacts from a combination of such indicators provides a more realistic diagnosis of ecosystem changes (e.g. ROCHET *et al.*, 2005). Using a combination of biological and economic indicators in a Traffic Light approach is a more general approach of particular use to fisheries managers (e.g. CERIOLA *et al.*, 2008).

Even prior to routine attempts to apply simple stock assessment theory which began in the 1960's, there was a well-developed biological understanding of the life histories of many species in FAO Area 37 (see e.g., Fig 1). In the Black Sea, the review of IVANOV & BEVERTON (1985) provided an acceptable starting point for ecological understanding, though the ecosystem itself has changed radically since that study, making it (and even that of PRODONOV *et al.*, 1997), a dangerous basis for generalizations. Information on life histories needs to be adequately integrated with stock assessment theory to explain many events, and rectifying deficiencies this way appears to be a priority.

As noted by LEMBO *et al.* (2002), the target of the bottom trawl fisheries is a species complex and not just a target species. A single commercial species may be caught by different fishing techniques or strategies, each concentrating their fishing pressure on individuals of different sizes. Approaches to integrating this type of multispecies data have been attempted elsewhere: thus, COLLIE & DELONG (1999) simplified food web studies in the Gulf of Maine, by applying a biomass-dynamic model to aggregated biomasses of different species which were either similar taxonomically, had similar exploitation histories, or had similar food preferences or similar trophic levels. Correlation analyses were also applied to the individual or aggregate time series with or without time lags being applied. This approach is compatible with the ideas of TYLER (1999) on managing multispecies fisheries by species assemblage, which seems a promising approach and is discussed next.

Assemblage analysis

Assemblages are groups of resident (i.e. non-migratory) species that statistically cooccur together over homogenous areas which can be mapped and in theory, managed as groups. TYLER (1999) suggested that: 'An assemblage maintenance approach may be the only way of achieving multispecies persistence', and suggested setting up areas of contrasting fishing effort based on a GIS map of assemblages. Comparing areas with similar fish communities, but where fishing intensity differs by at least three times, will allow comparative studies on their reaction to fishing. The new multiple GFCM fleet OU's seems ideally adapted to this procedure.

A simple diagnostic approach based on correlation: In the case of Mediterranean fine mesh trawl fisheries where 500 species or more may occasionally occur in surveys, we need to simplify the situation in a similar way, either by working with a) 'indicator species' or b) by identifying groups of species that behave similarly in relation to fisheries. COLLIE & DELONG (1999) applied group analyses of trawl data using correlograms to the simpler food web of the Gulf of Maine. This allowed biomass trends of groups of species to be identified, and greatly simplified the subsequent management recommendations. A biomass-dynamic model was then applied to the aggregates for each group of species.

Using cluster analysis to identify species assemblages

Following the concept of assemblage analysis, a very preliminary analysis was applied to data kindly provided by ARPAT, Livorno, Tuscany. The following is not a definitive analysis, but explores whether assemblage analysis could be useful for Mediterranean multispecies assessment. The general similarities of trends for many of the 500+ species taken in the GRUND data set was revealed by cluster analysis using hierarchical clustering and the Pearson correlation as an index of similarity (StatistXL software). An arbitrary value of r > 0,6 was chosen as a cutoff point to the correlogram in order to identify correlated pairs of species and construct the 'clusters' shown in Figure 5, which can be considered assemblages. (Three letter symbols correspond to species or species groups recognized in the surveys, some of which are identified in Fig 5).

Pairs of species in the correlation matrix for which r > 0.6 were selected: this value of r is highly significant, but is simply used here as a means of sorting a very large correlogram to reveal species showing similar trends, in order to place them into assemblages (TYLER, 1999). Those species with similar trajectories of kg/km^2 and r > 0.6 were then assembled into clusters (Fig. 6). Species showing similarities in Cluster 1 were *Mullus barbatus,* 2 species of *Pagellus,* and *Nephrops norvegicus.* No attempt is made here to determine the nature of the relationships between these species which might be a logical next step, but several species in cluster 3 show different habits: a pelagic species (*C. aper*) and two demersal species show similar trends. Cluster 2 is probably the most important commercially, and contains *M. merluccius, M. poutassou, Pagellus erythrinus* and 5 species of cephalopods. It would be justifiable in my opinion to focus mainly on these two groupings separately, since it is impractical to manage trends in abundance separately in a complex mixed species fishery. Pooling biomass and catch rate data for these groups, and modelling the grouped data, seems a time-saving operation. Figure 7 shows the trends in both survey biomass for species negatively cor-

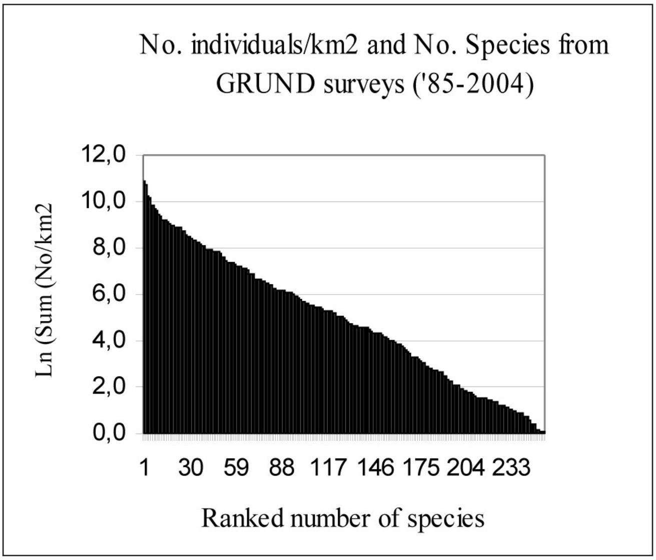


Fig. 5: A plot of ranked log (kg/km^2) by species in GRUND surveys, against number of species.

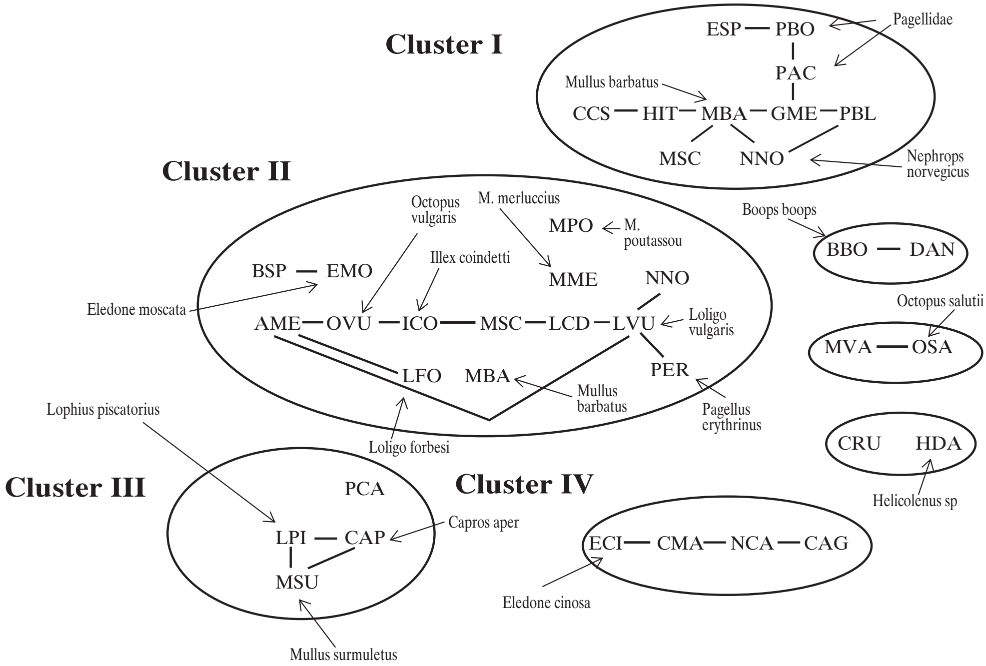


Fig. 6: Species assemblages grouping different species showing similar trends in the GRUND database, as revealed by cluster analysis (StatistXL package): key commercial species are identified.

related with fishing effort (r > 0.6) and effort. The trend over the period covered by the data was towards increased offshore trawling and a decline in inshore trawl effort, with species densities showing inverse trends to the 2 effort series. Although more careful analysis is recommended for this and similar MEDITS data sets, such an approach offers management the possibility of avoiding discussions degenerating into an unmanageable complex of recommendations by individual species.

Comparing trends of homogenous species clusters with inshore and deepwater effort trends. A further analysis of the GRUND data set was suggested, also incorporating time series for fishing effort measured separately for a coastal and a deep water fleet. This further cluster analysis of the two effort time series, together with the survey density trends by species, suggested some important features of exploited communities (Fig.7). Lower cut-off points for r were used on the new correlogram (r > 0.4), and both positive and negative relationships between species trends and fleet effort emerged. Further discussion here is restricted to species whose abundance was inversely correlated with either coastal or deep water effort, by showing a decline in biomass as fishing effort increased in intensity (Fig. 7).

Figure 7 shows a greater number of negative relationships between species biomass and coastal trawler effort than for the deep water fleet effort, perhaps because the larger inshore fleet exerted the greatest effort and caused the higher fishing mortality. Operations may not be independent between the two fleets however; many species were positively correlated with effort trends

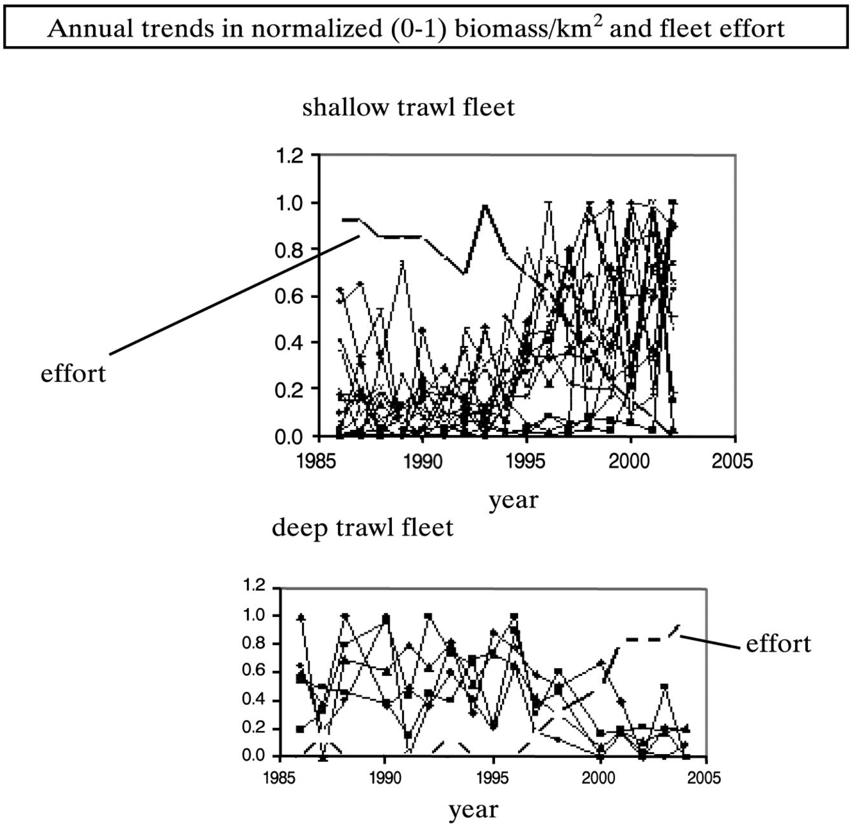


Fig 7: Comparison of effort trends (heavy line above, and dashed line below) with trends (individual lines) in the abundance of species negatively correlated with effort (two plots shown separately for shallow and deepwater fleets) – GRUND data set.

for one fleet, and negatively correlated with effort trends of the other. Alternative interpretations of the positive relationships are multiple: an inshore species may be recovering as effort declined, or perhaps a degree of interchange occurs between the fishing areas for the two fleets depending on conditions and markets. An increase in abundance of *Nephrops,* one of the key target species in deep water, may have led to its targeting. As suggested by Figure 7 however, negative relationships can be reasonably attributed to depletion by fishing.

Concentrating only on the groups of species showing a negative relationship with either inshore or deep water fishing effort trends (Fig. 8), the combined survey biomasses of these two groups were regressed on the respective fishing effort time series. The linear regressions are shown below:

Fleets	**Relationships**	**R^2**
Coastal fishery	$\sum$ Density (kg/km^2) = 1313.7 – 0.016* (Effort)	0.8
Deep water fishery	$\sum$ Density (kg/km^2) = 88.14 – 0.008* (Effort)	0.7

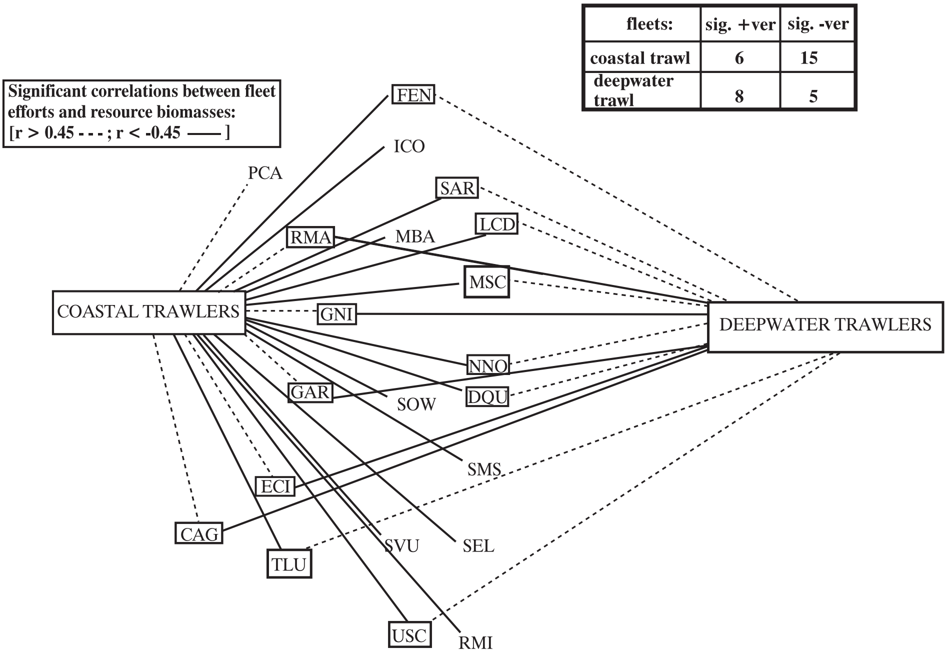


Fig 8: Numbers of significant cross-correlations between inshore and offshore fleet effort trends and biomasses in the period (1985-2004) for important species taken in the GRUND surveys off Viareggio and Livorno (data with permission from ARPAT). (Species symbols in 'boxes' show the frequent occurrence of opposite signs of correlations for the two fleets with most of the species illustrated here).

These linear regressions suggest that density levels for these two groups will drop to zero at 82,106 and 11,017 effort units respectively for coastal and deep water fisheries. To roughly estimate the Maximum Sustainable Yield from Figure 9 for these two groups of species and fisheries, we might assume a Schaefer model applies. This is drawn by hand for illustration as a dotted line (i.e. not fitted!) in Figure 9. Under this symmetric production model we could assume that fMSY occurs at close to half the effort level by which combined species biomasses in the two species groups are predicted to drop to zero. This crude analysis suggests that trawling intensity is well over fMSY in both cases, but especially for the inshore fishery. Further analysis along similar lines would seem possible using the MEDITS data.

WHAT INFORMATION DOES MANAGEMENT NEED?

What are the management measures, and what are the requirements for assessment advice?

The classic assessment approach is to specify a target for fisheries management, but this has been unsuccessful in preventing over-exploitation. Since the UN Fish Stock Agreement and the FAO Code were established, management decision-making is usually in response to the infringement of Limit Reference Points. An elaboration on this approach is for management to use an agreed fisheries control rule defined in terms of available indicator series and reference points.

Two approaches are usually followed nowadays by fisheries management bodies:

1) The classic approach of fitting a yield model to the data: Here, an optimum is agreed to, and an attempt is made to counteract departures from the optimum by regulatory measures (e.g. quotas or capacity control). It seems likely from Figure 9 that the majority of commercial species in the Mediterranean and Black Seas are already at or beyond the optimal fishing mortality rate, whether defined by $F_{0.1}$ or other precautionary RP. The key question is not whether, but to what extent, fishing effort needs to be reduced to restore species productivity.
2) A more recent approach requires assessment scientists and management to work closely together in defining and implementing a 'management rule' or 'control law' by defining unsafe values of indicators as limit reference point values (LRPs). When these are approached, some action has to be taken to restore the fishery to a safer condition. Such a control law needs defining in terms of LRPs which are indicator values agreed to represent the onset of dangerous conditions, and should specify the necessary actions to take when these are approached or exceeded. As noted by DOWLING *et al.* (2008), for data-poor fisheries, a harvest strategy incorporating a series of triggers needs identifying, in which applying spatial management strategies is precautionary. In fact, establishing a harvest control rule is perhaps the ultimate goal of fisheries management (BUTTERWORTH & PUNT (2003).

Stress is placed on the fact that stock assessment or determining reference points are not 'stand-alone' scientific exercises – they have little significance if not applied by management! An example of a management rule is the COMFIE-type rule suggested by ICES (1997). The underlying concept is clear: indicators and reference points are needed to drive a management rule. It is also important that the interface between science and management be well defined, and that the fishing industry understand the basis and utility of the reference points proposed.

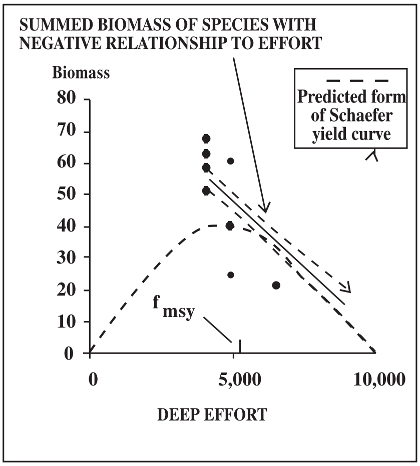
A general form for a fisheries management rule using multiple criteria:

IF: **R.Vessel $CPUE_t < CPUE_{Lim}$**
OR: **Spawning Biomass $_t$ < Spawning Biomass $_{Lim}$**
OR: **$F_t > F_{Lim}$**
OR: **$Z_t > Z_{Lim}$**
OR: **Bycatch (protected species)$_t$ > An established norm. (*)**

THEN: Annual fishing effort the following year t+1 should be reduced by X % annually until the above conditions have been reversed, and a safe spawning biomass or other criterion mentioned, have been re-established. Such a safe level of effort in year t+n would be established, for example, when:

Spawning Biomass $_{t+n}$ = Spawning biomass$_{Lim}$ * (100+Y)%]

– where Y is a positive number. *(* Other criteria could of course be used in the above list, such as mean size captured, species diversity, etc., where appropriate, or where other data measuring risk of stock collapse are available)*



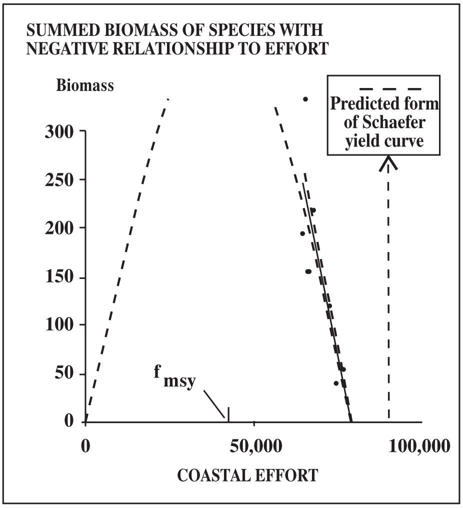


Fig 9: Relationship between deepwater fleet effort and the group of species negatively correlated with effort trends (LEFT), and similarly for the species negatively correlated with the inshore fleet effort series (RIGHT), showing the negative linear regressions. Assuming an intercept on the RHS implies commercial extinction, the f_{MSY} levels for the species groups should fall around the mid-point of the two intercepts on the x axis (Schaefer curves drawn by eye - for illustration only).

Three points can be noted in relation to the above hypothetical management format:

(a) The rule must be transparent, and understandable (and able to be modified) by non-experts, in the light of their perception of risks and benefits.
(b) The role of stock assessment workers is to provide options and estimates of (e.g.) F_{Lim}, Z_{Lim} and to estimate where the fishery is in relation to them.
(c) The rule should be able to use directly the best estimates from surveys (e.g. spawning biomass, CPUE) without necessarily running the data through a modelling exercise first if an agreement on limits has been reached.

3) *Stock recovery plans:* These also use a rule to control effort and ensure stock recovery. CADDY & AGNEW (2005) reviewed a range of fisheries where recovery plans have been used. This type of application presupposes another class of reference points, defining first, the fishing mortality and biomass levels at which recovery plan actions should be triggered, but also the target for spawning potential or biomass by which the population is considered to have recovered [e.g. $B_{LIM}*(1+ Y/100)$ in the above example]. *The reason for postulating a higher target than BLIM is of course to avoid oscillation around this dangerous point.*

Defining depleted stocks in the Mediterranean and Black Sea, and setting targets for their recovery, is now an appropriate activity for stock assessment workers. Lists of species for which recovery plans are urgently needed should be drawn up and applied!

In summary, once the infrastructure and internationally-agreed regulations are in place, a focus on indicators and reference points allows some form of management rule to be applied. The assessment-management framework to use with such an approach does not currently appear to be in place for most Mediterranean and Black Sea fisheries.

Some general conclusions where ecosystem linkages have been investigated from a fishery perspective elsewhere in the world are given in Table 1.

Although many of these conclusions seem aimed at management, they have obvious relevance to fisheries scientists and would be worth discussing in the Mediterranean context.

Table 1
Some common conclusions from work on fisheries ecosystems and from multispecies models applied to global marine fisheries.

1	The least productive species (i.e. those with the slowest growth rate, lowest fecundity and lowest natural mortality rate) will tend to become scarce first in a mixed species fishery.
2	The multispecies yield is less than the sum of the predicted optimal yields from single species analysis.
3	Consumption of pelagic fish and squids by predatory fish often equals or exceeds landings.
4	Multispecies models suggest the need for explicit trade offs between harvesting species with different productivities and economic values, caught by different fleet segments.
5	An overall principle for management is to keep key species within their normal ranges of natural variation as components of the biological community, or to facilitate their return to these ranges as soon as possible.
6	Technical guidance must be available that enables managers to develop measurable and reasonable goals and objectives. This information must be based on interdisciplinary approaches (e.g., Fowler et al. 1999).
7	Field experiments are needed in fisheries management: analysis of data or stock assessment alone will not resolve many questions raised in multispecies management – experimental management seems required to determine what are the 'leverage points' in the ecosystem.
8	Maximizing overall optimal yield at the multispecies level, either economically or in tonnage, is secondary to avoiding a loss of biodiversity and special habitats of critical importance.
9	If environmental change drives productivity (as in the Black Sea), we need to build environmental inputs into our resource advisory functions.
10	Do the Black Sea Environmental Commission and GFCM want to actively manage resources, or simply monitor changes? What is the proper interface and format between science and managers in these two cases?
11	Given the high value of many Mediterranean resources, we should be building bio-economic components into ecosystem models.

As depletion of global resources has become evident, the emphasis in the 1980s changed towards a concern with the causes of declining recruitment. Fecundity/recruit studies became common, especially since relatively few 'stock-recruitment relationships' (SRRs) have been developed so far for Mediterranean resources due to the difficulty of obtaining time series of recruitment and population age structure. (See however, ABELLA *et al.* (2005b) who fitted such a relationship for red mullet using MEDITS data).

The two main objectives that seem to emerge for the region that are relevant to assessment workers, are to provide a continuity of supply and the precautionary objective of preserving ecosystem integrity and preventing stock collapses.

Many assessment methodologies exist on the world stage, but it seems fair to say that deciding between methodologies must rely to a smaller extent on their mathematical efficiency, and more on the reality that stock assessments are based on data - the available data determines the approach, whether it is stock assessment, or general resource (e.g. ecosystem advice) that is needed. Avoiding obvious preconceptions suggested by commonly applied models also seems advisable. Finally, the management approach adopted dictates the type of assessment inputs required.

What are the management options without quotas, and what advice does management need?

In the absence of quota control, management's response to stock assessment advice will be largely a coarse control of effective capacity and access to the resource, as well as associated technical measures such as gear regulations, and seasonal or permanent closures of parts of the stock area. The wide variety of fishing gears in use in the Mediterranean means that effort measurement is problematic, and it is important to consider gear interactions (e.g., FARUGGIO ET AL. 1994, 1995). Aiming for short-term assessment advice that changes from year to year will therefore not be feasible in most cases.

Fine control of access (i.e. an allowable number of days fished) is in theory possible, but rarely if ever implemented, except for inshore fleets when the prohibition of fishing on certain days of the week is a control method that has low surveillance costs.

While quota control still remains a feasible option for targeted single-species resources (especially pelagics), it is not widely applied; this also affects the type of advice needed by managers. Ideally assessment advice should relate current levels of biomass and fishing mortality to those in the past, and to Limit Reference Points. The hope is that the overall fishing intensity will be controlled by rules on access, license numbers, and limits to fishing power, and that it will slowly converge on sustainable rates and methods of harvest. It will have to be accepted that the total harvest will fluctuate from year to year due to variable levels of recruitment. The question then, is what type of advice will managers require to achieve this objective?

Management's means of responding to resource advice in the Mediterranean will largely be confined to:

- a control of effective fleet capacity, license numbers, fishing power, and conditions of licensing, and/or control of access to the resource;
- application of associated technical measures including regulations on the gear;
- institution of seasonal or permanent closures of parts of the stock area;

- controls on investment in the sector and avoidance of subsidies;
- control of size at capture will be best achieved by closing nursery areas with less reliance on mesh sizes and legal minimum sizes landed, for reasons discussed.

SUMMARY

A number of questions which need to be addressed have emerged from this paper:

1) What time series of information are currently being collected on the key species, and of what type? If time series of catch, effort and size/age structure are being collected, established methodologies such as VPA and its derivatives, or production models, can be used. In many cases this is not the case, and this dramatically restricts the methodologies of assessment that can be used, and means that more emphasis will have to be placed on analysing indicator trends, and seeking control rules that do not require detailed data.
2) Reliable indicator series will be directly useful to management, especially if precautionary levels of these indicators (in other words LRPs) can be established, and with or without model output, indicator values can be used directly in fisheries control laws.
3) In the absence of time series, methods that assume equilibrium conditions should be used with caution. When working with the pseudocohort assumption, especially for fisheries on juveniles or where there is substantial discarding or incidental mortality of small fish, or where damage to nursery habitat occurs, it is important to refine the parameter values that apply at early exploited stages of the life history, otherwise inaccurate management advice will result from 'per recruit' or SRR calculations.
4) Where time series have been interrupted, they should ideally be restarted in a comparable way. An immediate priority would be to repeat earlier analyses from the 1970's and 1980's using comparable data, to establish the current situation with respect to these earlier 'equilibrium' studies, in order to guide management action.
5) Each assessment method mentioned here has pros and cons, and is characterised by specific assumptions, limitations and constraints. These should be made explicit. No single-species assessment method can be considered self-sufficient, and if used alone as an 'approved method', risks introducing hidden sources of bias into diagnosis and advice. Avoid facile transplanting of methods and assumptions from other areas where biological and socio-economic conditions are widely different.
6) All assessments should attempt to measure the substantial uncertainty inherent in their results. With these measures of uncertainty in hand, it is the responsibility of managers to reflect on the level of risk and precaution they are prepared to accept in their decisions. The only way to make the estimates as robust as possible will be to compare the results from different assessment strategies, especially using data from different sources where these are available.
7) Since environments are changing in part due to anthropogenic impacts, we need to use caution in interpreting results from models that assume that equilib-

rium conditions apply. Establishing indicators that measure environmental change and the degree of productivity of the system will be essential to precautionary management decisions.

8) Science must provide research, monitoring and assessment inputs for management, but also should evaluate progress towards the specific goals and objectives that are suggested to science by management. Stock assessment is often seen, inaccurately, as a scientific activity separate from the management process, and the interface between the two areas of activity, and their respective responsibilities, is often poorly defined.
9) Trawl survey data is one of the few sources of unambiguous information on resource and ecosystem change. Where catch sampling is unreliable, innovative approaches to analysis of survey data need to aim at monitoring biomass, overall mortality, and system productivity, and the use of this information directly, and not necessarily only after model fitting.
10) Ecosystem approaches must be developed, and should not be confined to trophic studies. They should compare ecosystem change with changes in indicators of fleet effort or capacity. It is important to consider the response of fish assemblages to effort change while making a multispecies assessment, and to be aware that the overall community change may be different from that for individual species.
11) In the case of shared stocks, it will not be possible to do much useful assessment if sampling schemes are not harmonized nationally, nor will much management be possible for shared stocks until national allocations of catches or national effort/capacity limits are agreed to. The issue of resource allocation in the Adriatic and Gulf of Lions has arisen in the past, and similar problems exist in other parts of the Mediterranean. Unless resolved, these detract from the feasibility of either multi-fleet capacity or quota control.
12) Especially in the Mediterranean, defining unit resources is still a problem – more work on the unit stock problem is necessary, including genetic characterisation.

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