ASSESSMENT OF THE STATUS OF THE COASTAL GROUNDFISH ASSEMBLAGE EXPLOITED BY THE VIAREGGIO FLEET

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(*WORK IN PROGRESS*)

Abstract- *A biomass dynamic model was used for the assessment of the status of the coastal groundfish assemblage exploited by the Viareggio fleet. Used data of catch and effort regards the years 1990-2005. Results suggest a high level of overexploitation and the need of a 30% effort reduction to drive species biomasses close to those furnishing the MSY and a further reduction if uncertainty is considered.*

Key-words: *biomass dynamic models, assessment, Mediterranean, multispecies fishery.*

Introduction – Understanding the population biology of fished species is necessary to maximize yields from the fishery without endangering the long term viability of the stock. Fishery scientists have been concerned with determining the maximum sustainable yield (MSY) that is the largest catch that can be made over extended periods of time without causing the collapse of the resources. Biomass dynamic models are mainly used for stock assessment when demographic structure of the catches is poorly known and age-structured models cannot be applied (Prager, 1994). This type of model results simple and this fact makes, from a scientific point of view, exploration of their properties easier and, from a management point of view, results easier to present and understand (Barber, 1988). Models assume that the current size of a population depends on interacting forces (individual growth, recruitment, natural and fishing mortality). By incorporating the three former phenomena into a single function they define the net effect at a particular stock size. They allow estimating current biomass, the pre-exploited stock biomass *K*, the intrinsic rate of population growth *r*, the maximum sustainable yield *MSY*, the level of effort or fishing mortality rates needed to reach the *MSY* (f_{MSY}, F_{MSY}). A recent version of such models was used for the assessment of the status of the single species and of the whole coastal multispecific groundfish assemblage exploited by the Viareggio fleet.

Materials and Methods - 16 years of collected data of landings and specific effort of the Viareggio fleet targeting the multispecies assemblage of coastal groundfish species were analysed (Abella *et al*., 2001). The population to be analysed (sampling frame) is constituted by all the vessels that operate along the year from the Viareggio port using bottom trawl nets and targeting demersal species. The size of the part of the fleet, with the above mentioned characteristics, progressively decreased along the analysed time period, from about 100 vessels to the current 80 vessels.

The basic survey design is a simple random sample, having all the vessels (sampling units), during every visit, an equal probability to be selected. In practice only about 40% of the whole active fleet targeting demersal species is on average sampled each time because the other ones didn't fish at all or arrive simultaneously with other vessels making practically impossible to sample them due to the reduced available human resources. Field work is performed by well trained staff and information is gathered on a monthly basis. Samples include the vessels belonging to all the size categories of the industrial fleet operating with all the fishing strategies and gears suitable for the capture of demersal species. Information on fishing operations is asked directly to fishers that have participated to this particular trip. Requested information includes used gears, fishing area, depth, number and duration of tows. Data regards the period 1990-2004.

The direct observation of landings allowed the quantification of the number of landed boxes by species, that were successively transformed in weight. The abundance index LPUE (landings per unit effort) was calculated for a selected number of species as "total weight in kg of the landed fraction/fishing effort" with effort expressed as effective hours fishing. Through a multivariate statistical approach, the catch composition was analyzed with the aim to define the species assemblages that characterize the landings of the vessels that have chosen each fishing strategy. The classification of trips can be made on a single-species basis, but each trip may be relevant for more than one species. For this reason it was decided to use an approach that considers the co-occurring species by fishing strategy and/or gear. The species assemblages so defined should represent invariant (at least seasonally) groupings by fishing gear and strategy and provide an accurate description of the commercially exploited species mixes. Multivariate data of the catch assessment survey were analyzed with the divisive hierarchical clustering technique included in the S-PLUS 4.5 package (MathSoft, 1999). The Euclidean distance (y-axis) was used as a measure of dissimilarity. The used algorithm defined fairly well the main fisheries present in the area operating from the Viareggio port. The analyses presented here regards the main fishery of the Viareggio fleet namely the

coastal fishery of trawlers operating near the coast and targeting a multispecific demersal assemblage. The analyses were performed on the 8 species that account for 65% of the mean total landings of the mentioned fishery (*Squilla mantis*, *Sepia officinalis*, *Mullus barbatus*, *Merluccius merluccius*, *Penaeus kerathurus*, *Eledone cirrhosa*, *Gobius niger* and *Trigla lucerna*) and on the whole species assemblage.
Data collected were stored in a special data base in Microsoft Access. The georeferenced information regarding fishing effort by vessel, effort distribution, fleet composition, fishing strategy, species, period, was represented and analyzed using the specially designed application MLFD (mapper of landed fish data) (Fortunati et alii, 2001, Abella et alii, 2001) based on ArcView GIS (ESRI,1996). The two systems (ArcView GIS and Access) communicate by using the Open Database Connectivity (ODBC) protocol to access the structured query language (SQL) server using external programs.
A special routine makes an automatic distribution of the daily amount of effort of one vessel (as well as of its daily catch) among the squares that were defined for the vessel operation during this single trip. The effort distribution pattern (for the total fleet, by fishing gear, by single vessel, by day, by season) and the respective distribution of catch rates for each one or for a selected number of commercial species can be displayed through thematic maps. Interpolation of catch rates of pooled species and effort by gear can be done with the ArcView GIS options available in the Spatial analyst module, that include “krigging”, “spline” and “inverse weighted distance” methods.
The catch performance of vessels of different size belonging to the same métier were compared by correlating catch rates obtained in the same time and place with the main structural characteristics of the vessels (size, power, gross tonnage).
In order to assess the current situation of these stocks and of the whole assemblage, a Limit Reference Point (in this case the Maximum Sustainable Yield) was chosen. The analyses were performed using the ASPIC.5 software (A Stock-Production model Incorporating Covariates) (Prager, 1994, 2005). This program implements an non-equilibrium, continuous-time, observation-error estimator for the production model (Schaefer, 1954, 1957; Pella, 1967; Schnute, 1977; Prager, 1994). ASPIC incorporates several extensions to classical stock-production models. One extension is that ASPIC can fit data from up to 10 data series that can be catch-effort series (from different gears or different periods of time), catch-abundance-index series, biomass indices, or biomass estimates made independently of the production model. Moreover ASPIC can fit a model under the assumption that yield in each year is known more precisely than fishing effort or relative abundance so fitting can be statistically conditioned on yield, rather than on fishing effort or relative abundance. The model is used to estimate r (intrinsic rate of population growth), MSY, ratio of current biomass or F to the biomass or F values at which MSY can be attained, and q (the catchability coefficient, the proportion of total stock taken by one unit of fishing effort). The software fits several dynamic versions of production models, it allows to modelise simultaneous or sequential fisheries and may “tune” the model to a biomass indexes from independent sources (ie. trawl surveys data). It allows to make yield forecasting and to derive precautionary target reference points based on the model defined limit reference points f_{msy}, F_{msy} and B_{msy}, facing the intrinsic uncertainty that characterise the analysed processes and the observation errors.
Biomass dynamic models assume that changes in the size of a fish population are caused by the interaction among four competing factors. Stock size will increase as a result of tissue growth as well as recruitment into the population of young fish which have become large enough to be selected by fishing gear and have migrated to the fishing grounds. Natural and fishing mortality are effects which reduce the population size. In particular:

Next biomass = last biomass + recruitment + growth – catch – natural mortality.

The two sources of increase in the population are the recruitment of new individuals (births) and the gain in weight by individuals already present in the population. Catch and natural mortality constitute the two sources of loss. In the absence of fishing the two terms, recruitment and growth, can be combined into a single term called production. If production is greater than natural mortality, the population will grow and in the opposite situation will decline. Surplus production is the algebric sum of recruitment, growth and natural mortality. The adjective “surplus” refers to the surplus of recruitment and growth over natural mortality (net production). It represents the increase of the population biomass in absence of fishing, or the amount of catch that can be taken while maintaining the biomass at a constant size. So a biomass dynamic model can be written as:

New biomass = old biomass + surplus production - catch

Biomass dynamic models are either discrete or continuous (Schaefer, 1954; Pella and Tomlinson, 1969; Walters and Hilborn, 1976; Butterworth and Andrew, 1984) and traditionally they are based on the differential equation governing the resource biomass.

The differential form of the equation is:

$$dB/dt = g(Bt) – qft\ Bt$$

where:
q is the catchability coefficient and
ft is the effort for year t.

In the simplest production model, the logistic or Graham-Schaefer (Graham, 1935; Schaefer, 1954, 1957) model, a first-order differential equation describes the rate of change of stock biomass Bt due to production. In the absence of fishing, the population's rate of increase or decrease is assumed to be function of the current population size only:

$$dBt/dt = rBt(1-B/K)$$

where:
Bt is the population biomass at time t;
r is the intrinsic growth rate parameter;
K is the average unexploited equilibrium biomass (carrying capacity), and
C is the catch measured as a rate.
The magnitude of production dB/dt as a function of stock biomass B, in the case of the Schaefer model, is assumed symmetrical around Bmsy (the biomass that can produce maximum sustainable yield). In fact, surplus production will be zero at a zero biomass and is maximized at a biomass of K/2.
MSY and the associated effort or fishing mortality that generates MSY (Fmsy and fmsy) given the respective biomass (Bmsy) are basic reference points estimated from surplus production models.

Results - The model allowed to estimate for each species, the parameters *r*, *K* of the logistic population growth curve, the catchability coefficient *q*, the *MSY* and corresponding levels of fishing effort *f* and fishing mortality rate *F*. The current level of *f* and *F* for each species resulted higher than their corresponding levels of f_{msy} and F_{msy}. Despite the general overexploitation status, the observed modest but progressive decrease of fishing pressure has probably generated stability or, for some species, positive trends in catch rates and biomass. Same signals derive from the forecasting routine.
The prediction ability of the future catch rates based on previous years was very satisfactory. A 40% reduction of fishing effort should drive yields for almost all the species close to *MSY*. For precautionary management purposes, considering the high level of uncertainty, it results necessary to set a target level of effort that while maximizes yields guarantee that effort will stay below the limit reference point F_{msy}. The routine REPAST (Ratio Extended Probability Approach to Setting Targets) (Prager *et al.*, 2003) was used for this purpose. The routine considers the variability of the estimates obtained by bootstrapping. Results suggest, considering the variability (CV), the need of a further reduction of effort ($f \cong 0.5*f_{current}$) in order to not exceed, with a statistical probability of 80%, the limit reference point.
(editing of this part is still in progress)

Conclusions - The use of a biomass dynamic model with data on landings and specific fishing effort allowed to perform a stock assessment of the coastal species assemblage exploited by an important fraction of the Viareggio fleet. Estimates of *MSY*, F_{msy}, *q*, *K* and *r* and other parameters useful for stock assessment are presented for each species. ASPIC.5 and related routines allowed to include some considerations related to management advice linked to the uncertainty mainly due to the imprecise knowledge of parameter values of a model or the magnitude of the system variables.
The species that constitute the assemblage exploited by the coastal groundfish fishery of Viareggio suffers a very high fishing pressure. It is likely that the modest reduction of fishing effort occurred along the analyzed period had produced for some species a light biomass enhancement. However, considering the current yields related to *MSY* and based on a precautionary approach, a strong reduction of fishing effort should be necessary. (editing of this paragraph is still in progress)

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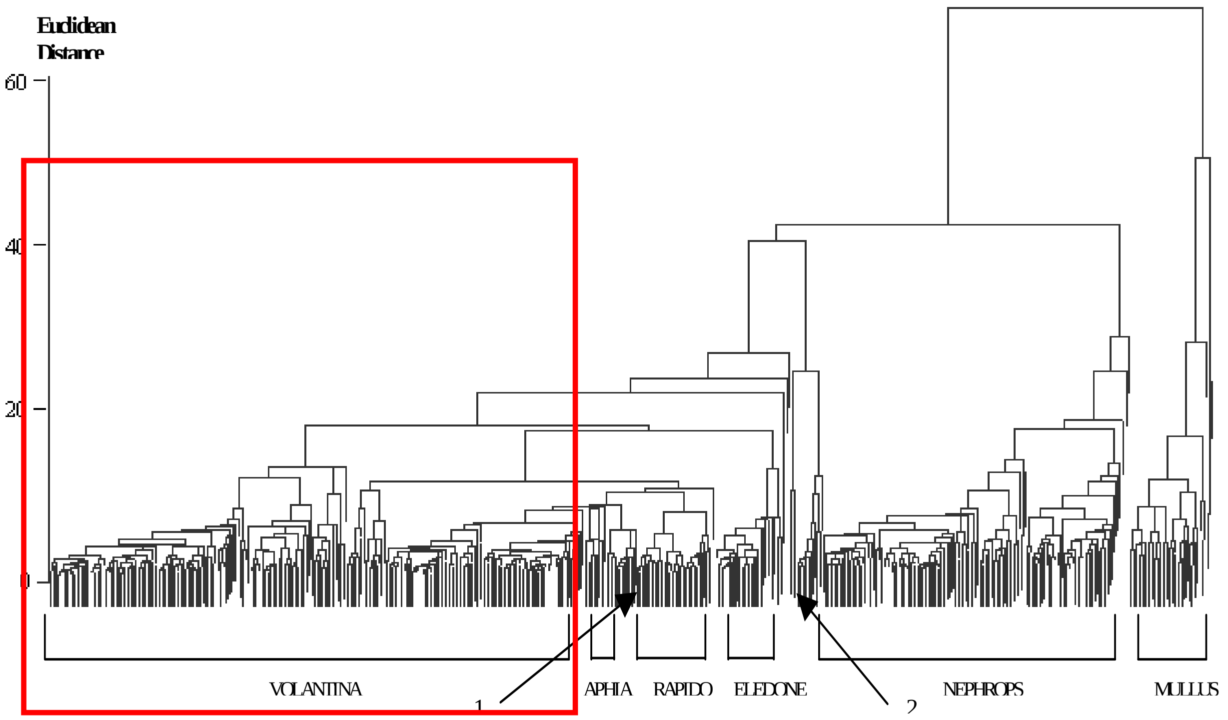
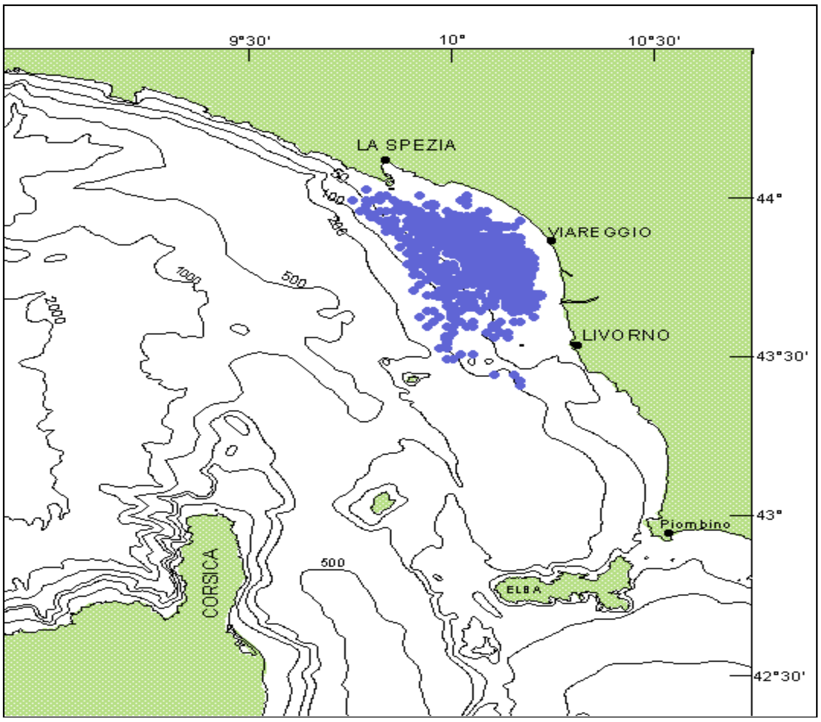


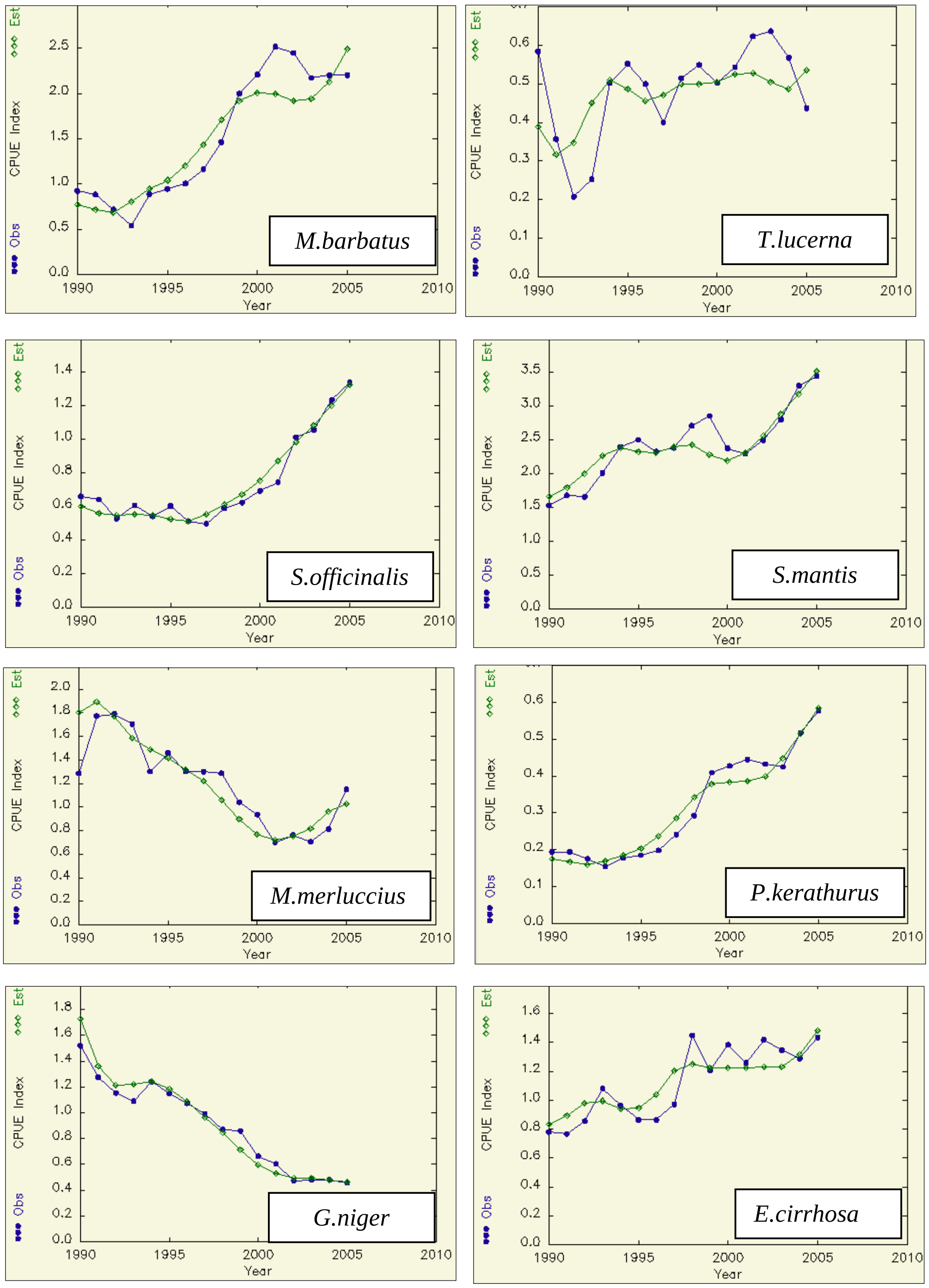
Clusters defined with the divisive hierarchical clustering option of S_PLUS. The Euclidean distance (y-axis) was used as the measure of dissimilarity. The red square highlights the coastal demersal assemblage.



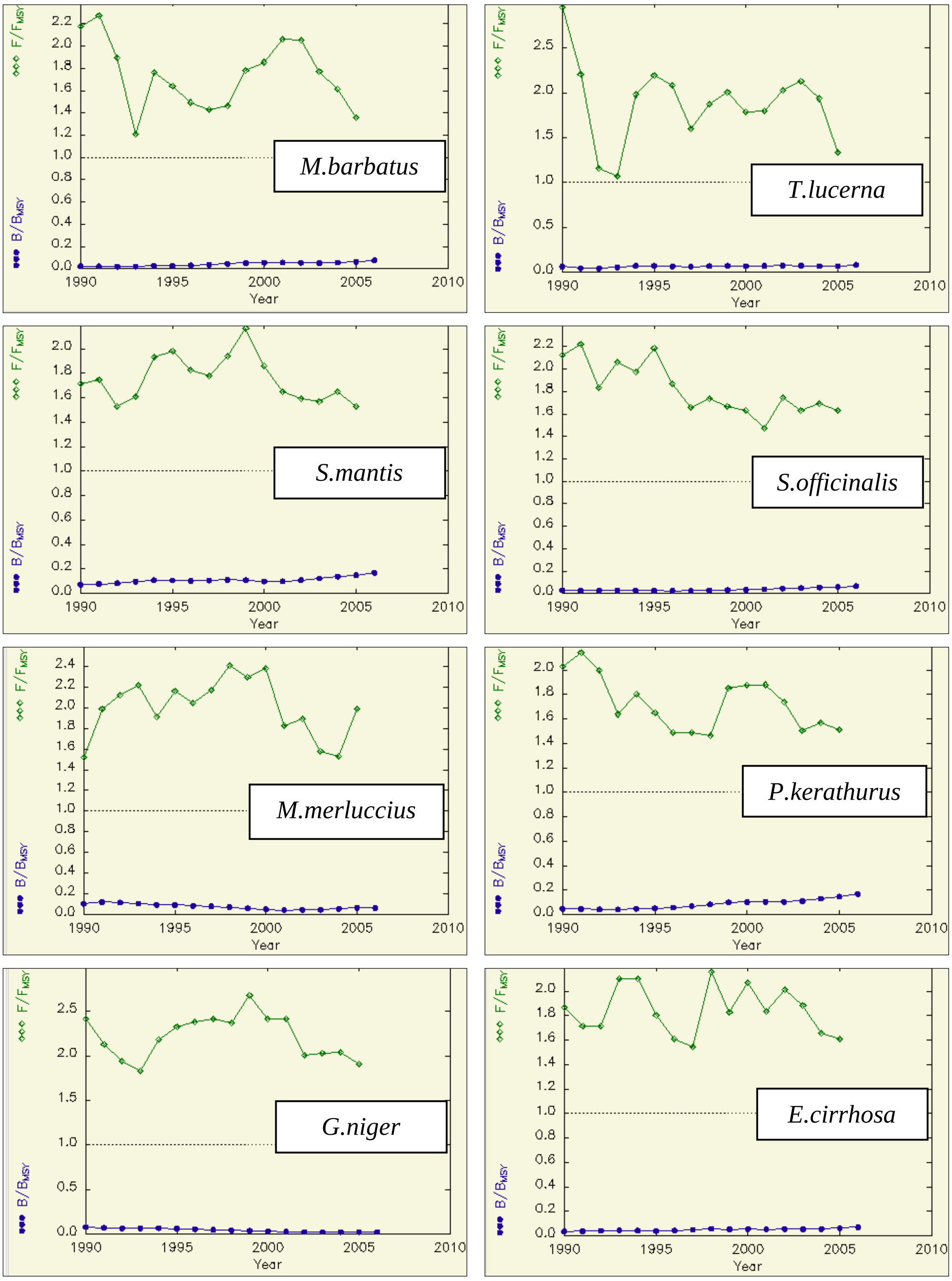
Spatial distribution of fishing effort of the coastal demersal assemblage fishery of Viareggio along the year

VOLANTINA		
SPECIES	CODE	%
Squilla mantis	SMS	21.8
Sepia officinalis	SOF	11.8
Mullus barbatus	MBA	9.5
Merluccius merluccius	MME	4.7
Penaeus kerathurus	PKE	4.6
Eledone cirrhosa	ECI	4.5
Gobius niger	GNI	4.2
Trigla lucerna	TLU	4.0
Trachurus mediterraneus	TME	3.1
Eledone moschata	EMO	3.0
Raja asterias	RAS	2.9
Solea vulgaris	SVU	2.8
Conger conger	CCO	2.3
Octopus vulgaris	OVU	1.9
Arnoglossus laterna	ALA	1.6
Trachinus draco	TDR	1.1
Alloteuthis media	AME	1.1
Other species	OTHER	15.00

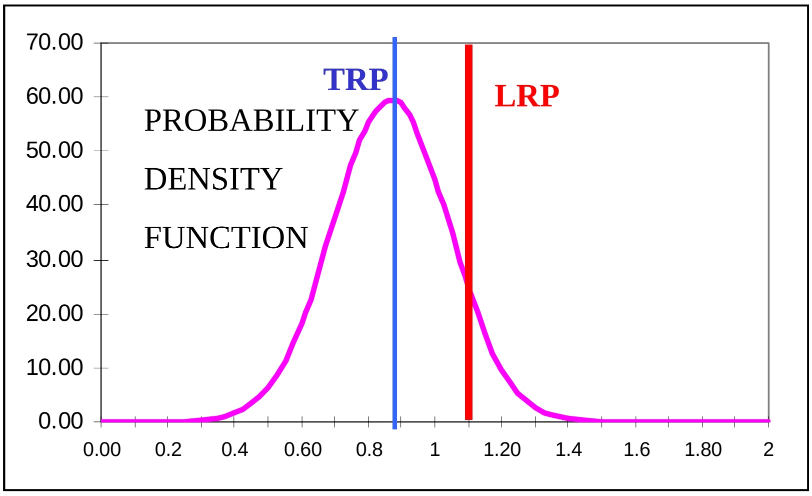
Average proportion of the single species in the landings in weight in the coastal fishery (yearly basis).



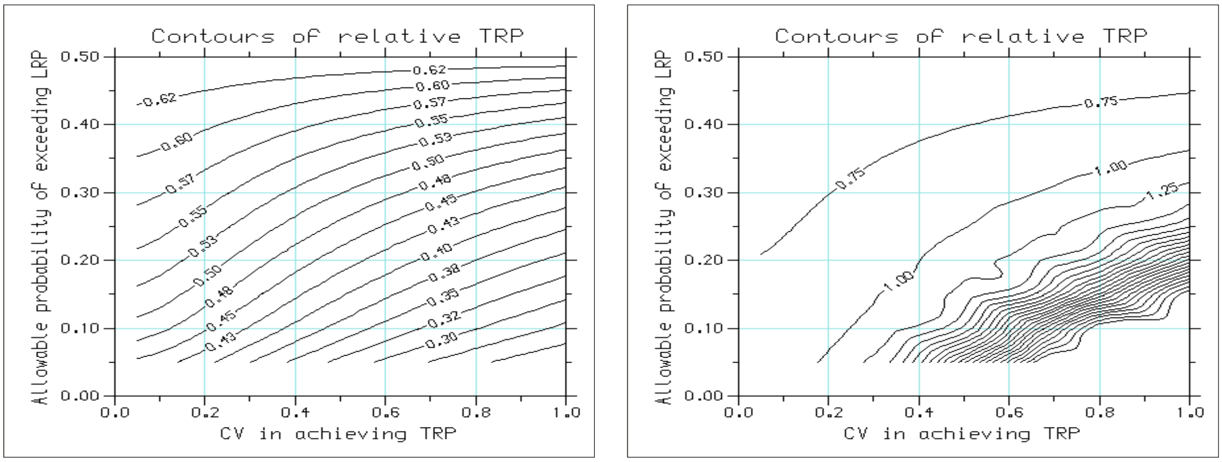
Observed and estimated trends of LPUE's for the 8 selected species



Trends of Fcurr/Fmsy and Bcurr/Bmsy rates for the 8 selected species



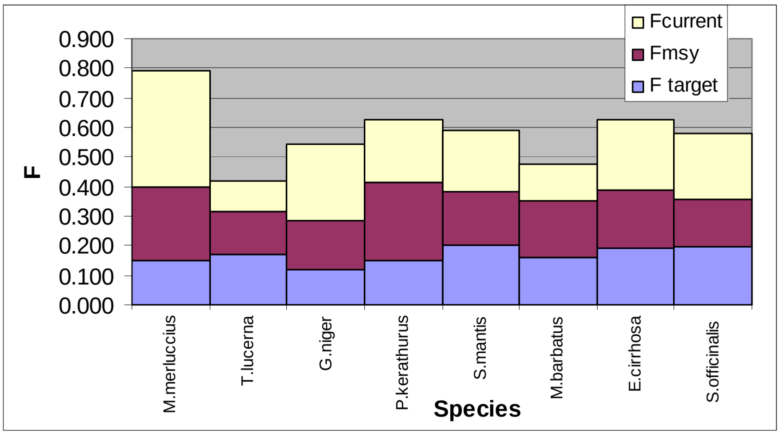
Probability density function showing the value of the Limit Reference Point and the value of the Target Reference Point defined considering the variability of the estimations and the allowable probability that the TRP exceed the LRP (in this case 20%).



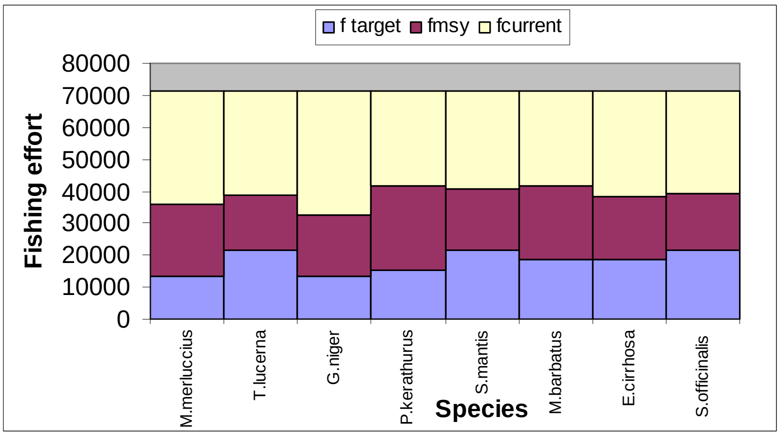
Contours of dimensionless Target Reference Points Fcurrent/Fmsy (left) and Bcurrent/Bmsy (right) calculated via the ratio-extended probability approach to setting targets (REPAST) with normal uncertainties (will be presented one couple of these graphics for each species).

Species	k	r	q	MSY	Bmsy	Fmsy	fmsy	LRP	TRP
M.barbatus	8.708E+06	0.698	8.395E-06	1.52E+06	4.354E+06	3.492E-01	4.16E+04	0.737	0.452
T.lucerna	1.771E+06	0.628	8.057E-06	2.782E+05	8.857E+05	3.141E-01	3.899E+04	0.749	0.545
S.mantis	4.692E+06	0.769	9.390E-06	9.016E+05	2.346E+06	3.843E-01	4.093E+04	0.654	0.576
S.officinalis	4.738E+06	0.710	8.999E-06	8.410E+05	2.369E+06	3.550E-01	3.944E+04	0.613	0.547
M.merluccius	2.837E+06	0.800	1.114E-05	5.672E+05	1.418E+06	3.999E-01	3.591E+04	0.504	0.371
P.kerathurus	7.400E+05	0.830	9.970E-06	1.535E+05	3.700E+05	4.149E-01	4.161E+04	0.662	0.367
G.niger	4.479E+06	0.571	8.807E-06	6.390E+05	2.239E+06	2.853E-01	3.240E+04	0.524	0.447
E.cirrhosa	4.375E+06	0.776	1.013E-05	8.484E+05	2.188E+06	3.878E-01	3.828E+04	0.622	0.523

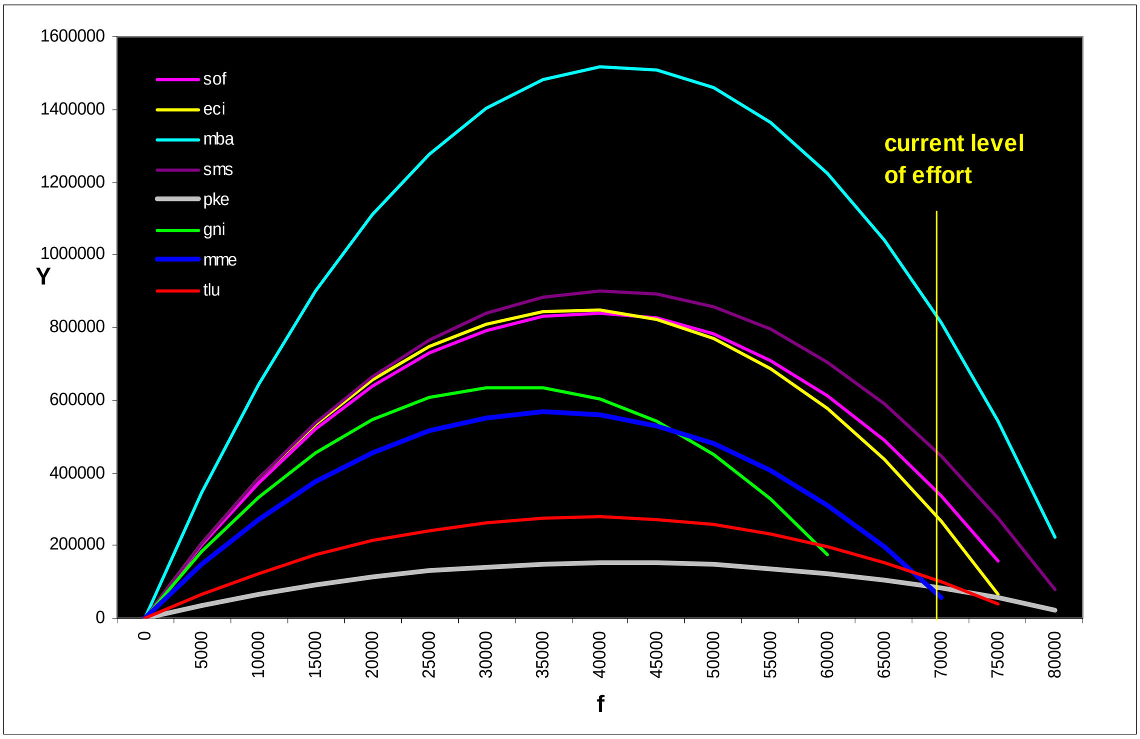
Main results for the 8 selected species. K and r of the population growth model, q=coefficient of catchability; MSY=Maximum Sustainable Yield; Bmsy= level of Biomass corresponding to the MSY; Fmsy= level of Fishing Mortality Rate f corresponding to therate that furnishes the MSY; LRP= reduction of the current level of F (Fcurr) necessary in order to reach the Fmsy; TRP= reduction of the Fcurr necessary to reach a precautionary reference point positioned below the Fmsy value that allows to be reasonably sure (P=80%) that fishing at this exploitation rate will not exceed Fmsy.



Estimated rates of current F, Fmsy and Ftarget for the 8 considered species



Estimated levels of a Limit Reference Point for fishing effort (*f*msy) and of a more precautionary Target Reference Point (*f*target) for each one of the 8 species considered.



Equilibrium Yield curves assuming a Schaefer model for the 8 species