GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN

COMMISSION GÉNÉRALE DES PÊCHES POUR LA MÉDITERRANÉE

Scientific Advisory Committee
12th Session of the
Transversal section of the Sub - Committees
Malta, 29 November 2010

Progress on the use of biological indicators and development of reference points for single species stock assessment

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Reference points and indicators are tools useful to implement a successful management scheme

The main features of an effective management scheme:

1) **General goals**
2) **Specific objectives**
3) **Information and data**
4) **Stock assessment models and procedures**
5) **Reference points and indicators**
6) **Management advice**
7) **Management implementation**
8) **Monitoring, surveillance and control**

Different kind of goals which may be in contrast each other

- Yield
- Income
- Labour
- Biodiversity
- …….

…a winner management strategy should be identify priorities…..

The Reference points can be defined as conventional values of the state of a fishery or a population that are considered the desirable objective to be reached (*target reference points*) or an undesirable state of the fishery which needs to be avoided (*threshold* or *limit reference points*)

Limit and Target RPs

Limits are:

- **F's you shouldn't exceed, a biomass you shouldn't go below**

Targets are :

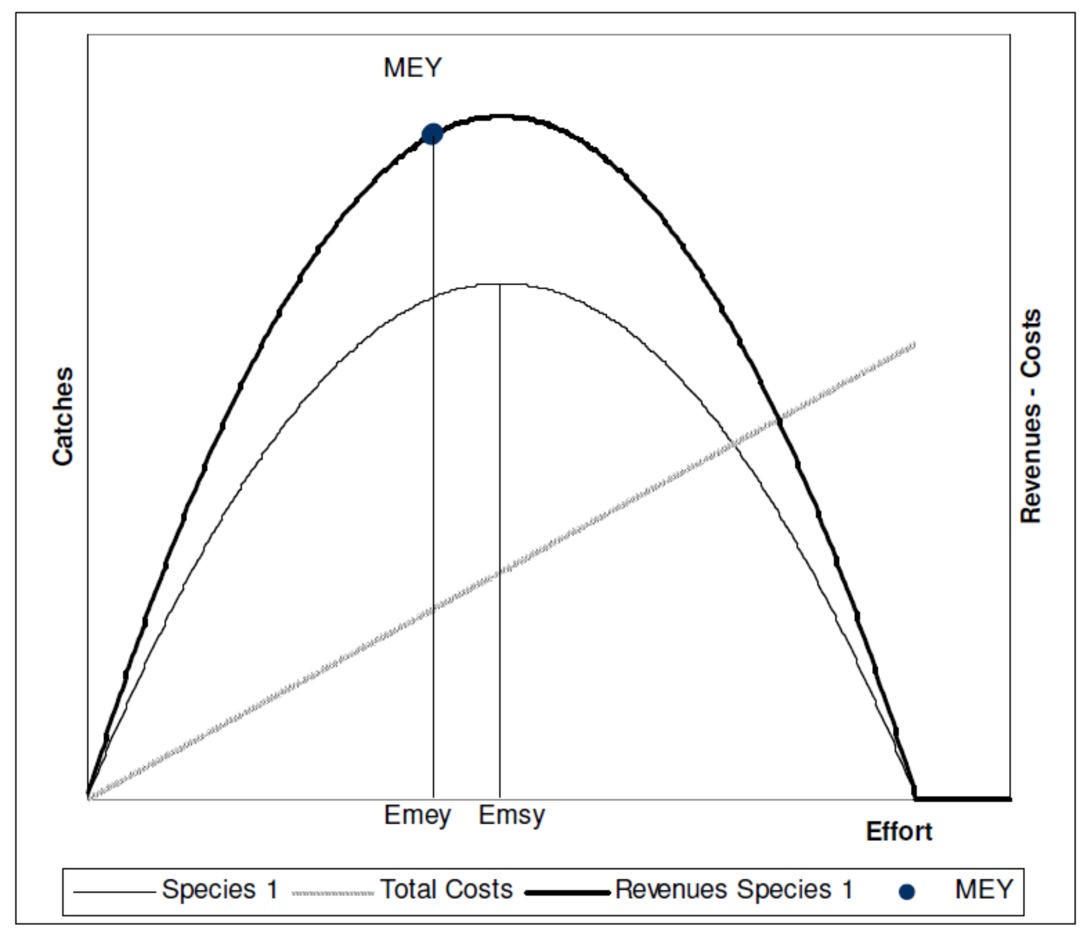
•a value we would like to attain

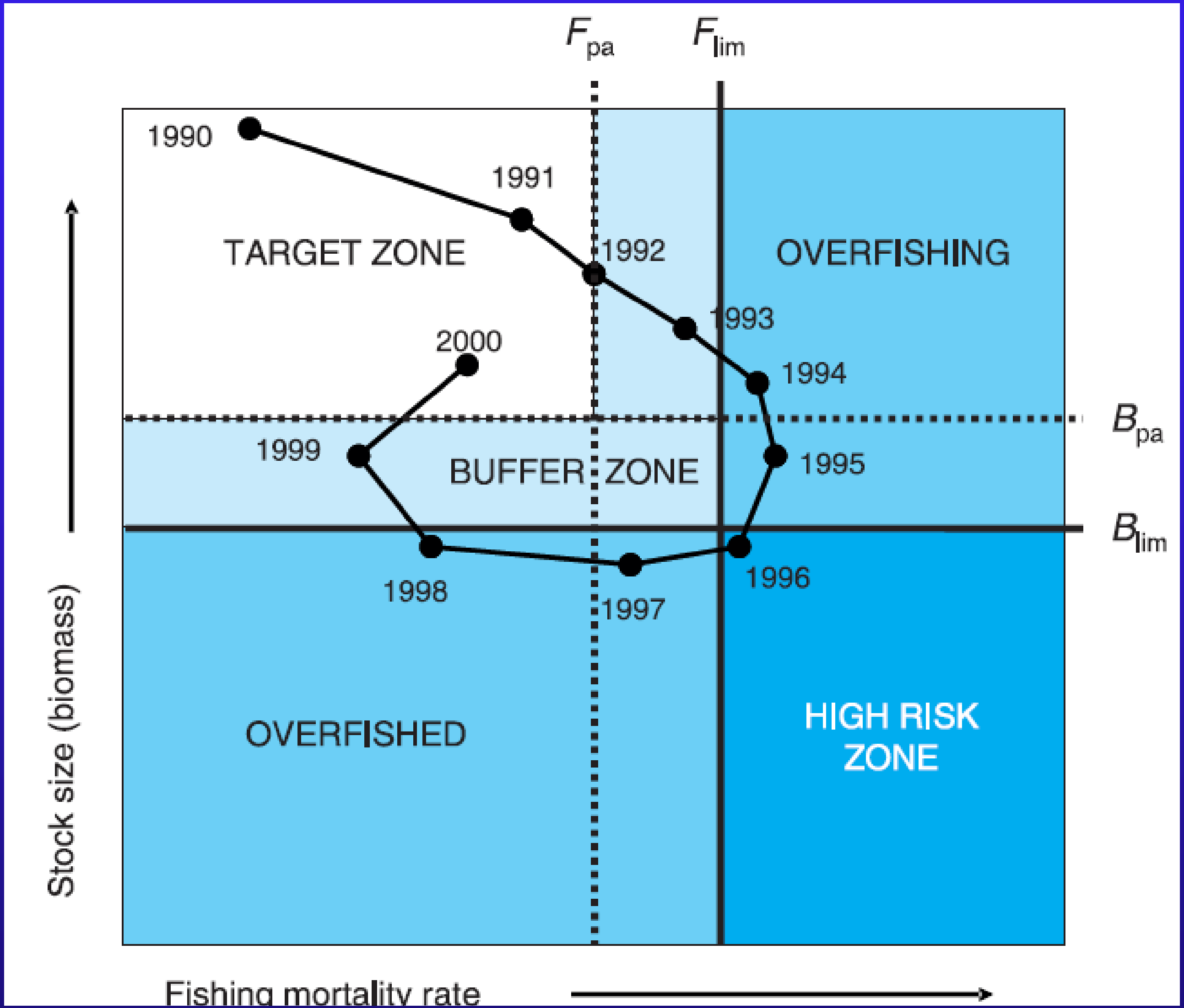
MORE COMMONLY USED BIOLOGICAL REFERENCE POINTS

	Theoretical basis	Data and model needs	Target or limit?
Reference points based on production models			
F_{MSY}	Fishing mortality at maximum sustainable yield	Surplus production	Limit
f_{MSY}	Fishing effort at maximum sustainable yield	Surplus production	Limit
Z_{MBP}	Fishing mortality at maximum biological production	Surplus production	Target or limit?
Reference points based on yield-per-recruit			
F_{MAX}	F at Maximum yield per recruit	M and growth parameters	Limit
$F_{0.1}$	Slope of the Y/R that is 10% of the slope at origin	M and growth parameters	Target?
F_{crash}	Fishing mortality for stock extintion	Dynamic pool, S/R,	Limit
Reference points based on Spawning Stock Biomass			
$F_{40\%}$	F that allows survival 40% of SSB at F=0	M and growth parameters	Limit
F_{low}	F that allows stock replacement in 90% of the cases	S/R and SSB/R	Target?
F_{med}	F that allows stock replacement in 50% of the cases	S/R and SSB/R	Limit
F_{high}	F that allows stock replacement in 10% of the cases	S/R and SSB/R	Limit
F_{loss}	F that allows replacement at lower observed stock size	S/R and SSB/R	Limit
Biomass-based reference points			
B_{loss}	Lower observed stock size that allows replacement	SSB and S/R	Limit
B_{pa}	Biomass below which probability of a drastic reduction of recruitment is increased	S/R	Limit
B_{MSY}	Biomass at maximum sustainable yield	Surplus production	Limit
$B_{50\%R}$	Biomass at which recruitment is 50% of its maximum size	S/R	Limit
$B_{20\%}$	Biomass at 20% of its pristine level	Dynamic pool or Surplus production models	Limit

The Maximum Economic Yield (MEY) is equal to the level of effort in which the maximum profit is achieved. In other words, it corresponds to the highest difference between revenues and total costs. Given the cost function as linear, the MEY value is positioned before and below the MSY.

The economic based RP





The history of a hypothetical fishery monitored over time for both stock-related and fishing-related indicators..

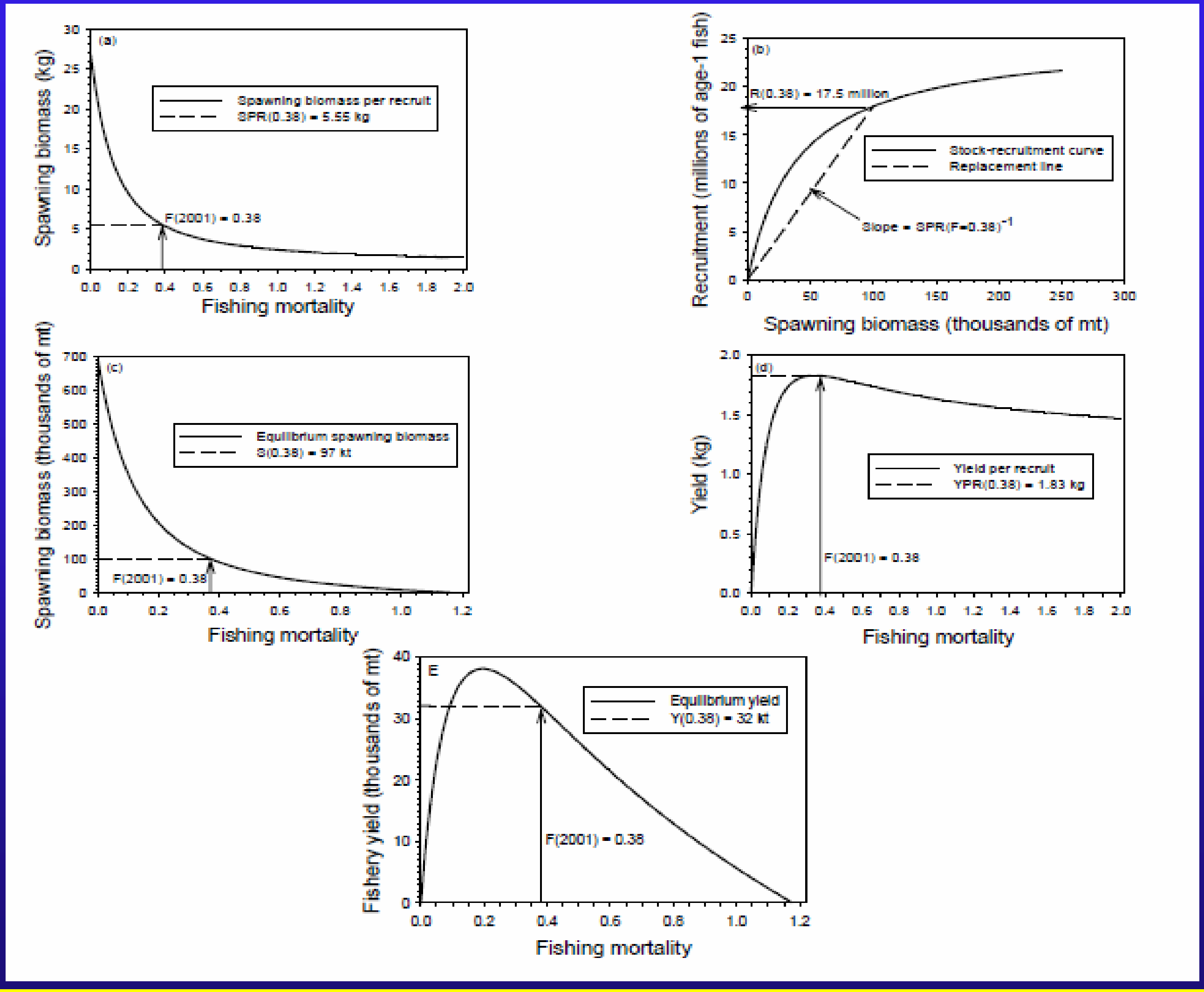
In this example, the fishing pressure became too high in the mid 1990s, rising first above the precautionary reference point, Fpa, and then above the limit reference point, Flim. The stock size then declined to an overfished state below both Bpa and Blim, but recovered to the safe 'target zone' when the fishing rate was reduced.

How to estimate MSY?

two ways for estimating production models and MSY reference points.

- **Use of traditional or variants of surplus-production models.**
- **Use of approaches based on spawner/recruit, yield-per-recruit, and biomass-per-recruit calculations.**

Production models using Yield per recruit + stock/recruitment



A standard Sissenwine-Shepherd analysis can be applied to compute MSY reference points

Long-term management targets as F_{max} or $F_{0.1}$ are non precautionary for small pelagic fish.

The use of reference points as F_{med} and F_{high} that take account of stock and recruit data is **unsuitable** in developing fisheries because **too much data demanding**.

A simple model was fitted to medium-term (about 10 year) periods using data of 28 stocks of small pelagics.

The model was used to estimate likelihood of stock decrease at different exploitation rates.

The pelagic stocks included in the model appeared to be in equilibrium for an exploitation rate of $F/Z=0.4$. This rate may be used as a **guideline for the appropriate exploitation of pelagic stocks (Patterson, 1992).**

Stock/Recruitment based approaches

RECRUITMENT OVERFISHING: "the level of fishing pressure that reduces the spawning biomass of a year class over its lifetime below the spawning biomass of its parents on average".

The approach is based on the concept of replacement used in ICES (Sissenwine and Shepherd (1987).

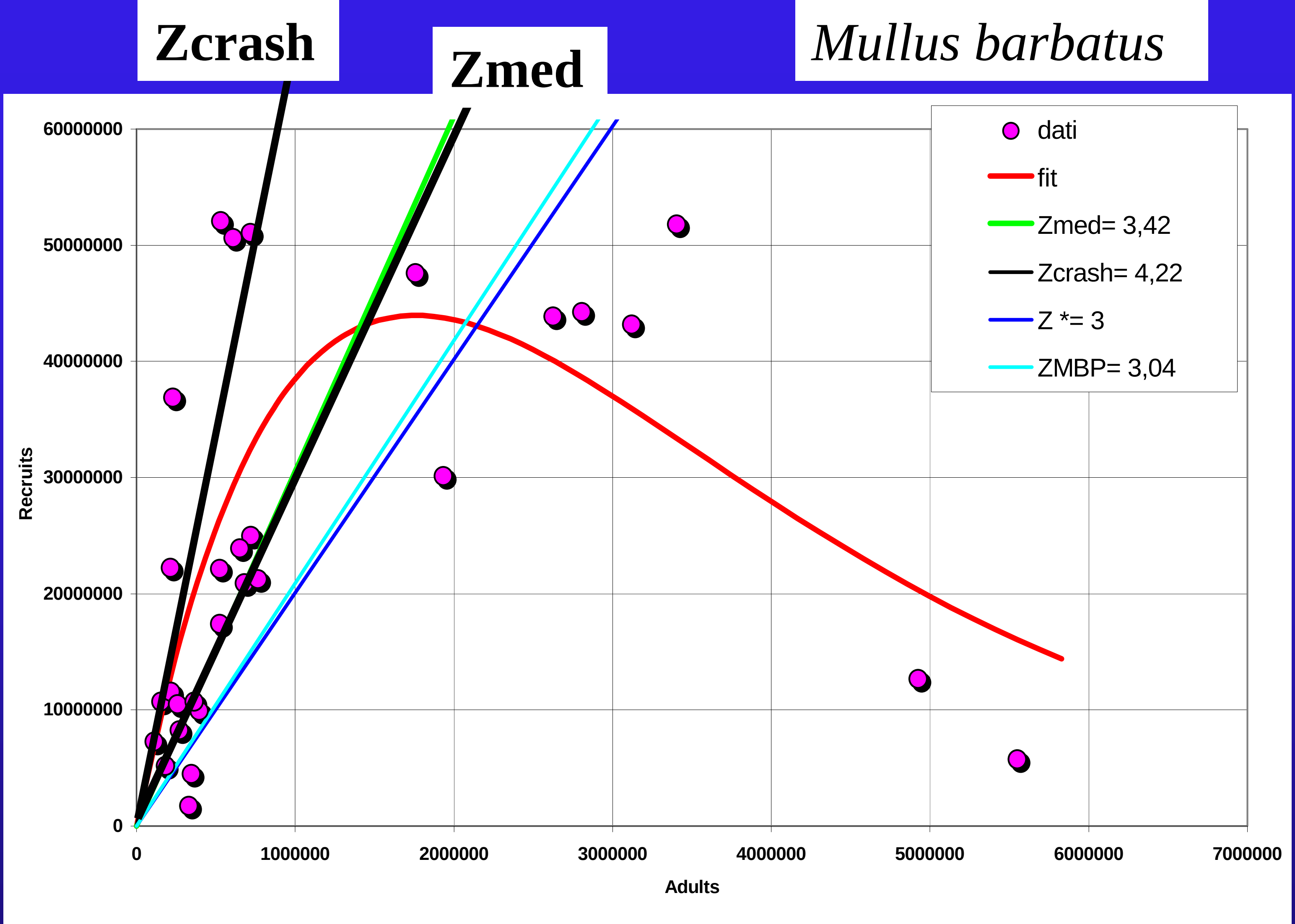
It allows the identification of the level of fishing mortality linked to the replacement of the spawning biomass that should guaranty adequate and sustainable yields.

Estimates of parent stock (numbers per Km^2) and respective number of recruits per Km^2 are coupled and displayed in a scatter diagram of stock/recruitment. The reference points Zcrash and Zmed can be estimated.

Zmed corresponds to the line representing an average survival at which stock replaces itself. It corresponds to the Z where recruitment in about half of the years overbalances losses due to mortality.

Zcrash is the level of Z corresponding to the intersection of the yield and fishing mortality relationship with the Z axis as estimated by an Z-based production model.

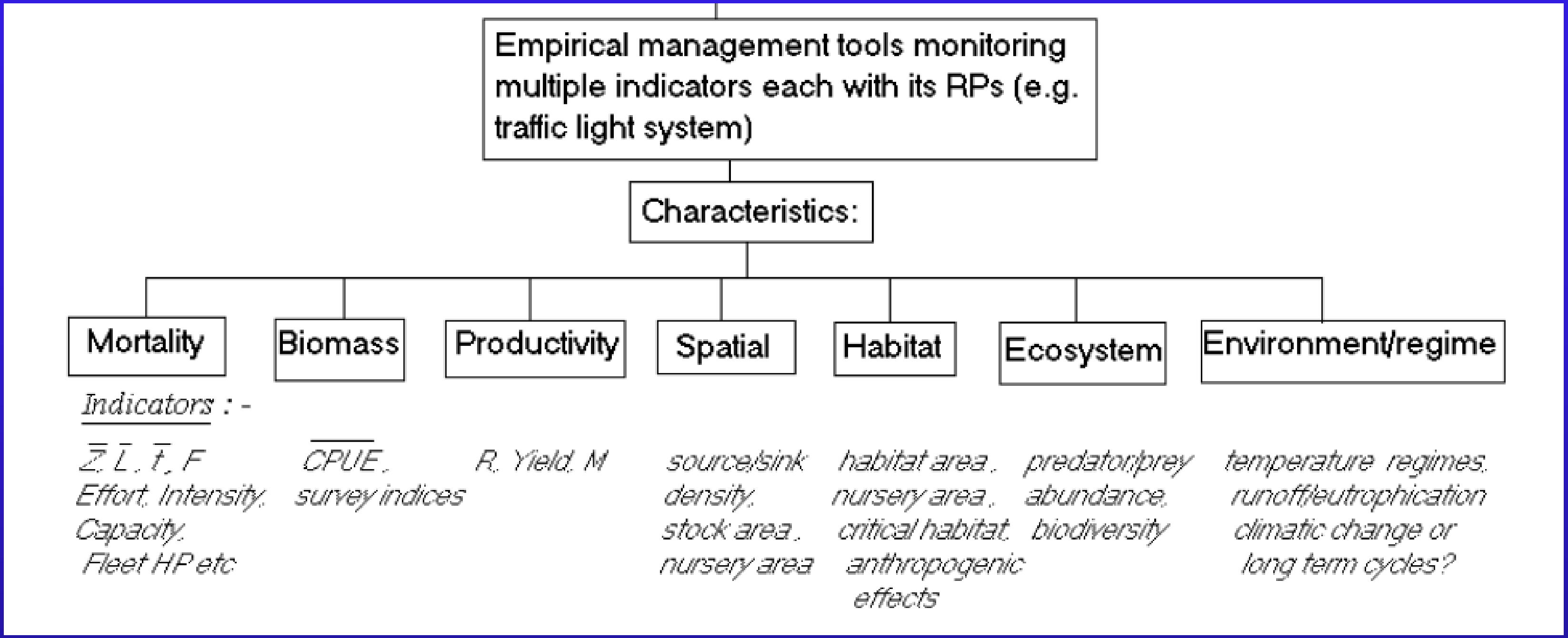
Mullus barbatus



Num. data	R^2 regr	alfa'	beta'	med R/A	Zmed	Zcrash
29	0,601	4,219	7417592	30,5	**3,42**	**4,22**

What is an indicator in fisheries science?

A specific pointer, or variable, which can be monitored in a system (e.g. a fishery) to give a measure of the state of the system at any given time. This indicator needs to be sensible (in positive or negative) to the effect of fishery on stock in order to track the state of the fishery.



An empirical probability distribution function may be created from a time series of values, which are first ranked, and then the observed range for the variable during the time series is divided into quartile.

In absence of better BRP, the lower quartile of the indicator, can be adopted as Limit Reference Point (for example as Blim).

Indicators

- Only when changes in a variable are greater than the level of uncertainty of a change (increase in B, decrease in Z, etc) they can be considered as "power" indicators
- "In the case indicators have to be aggregated, weighting is necessary and the relative importance of each one has to be defined by experts or based on management policy priorities.

Indicators for measuring the fishing impact on singe species stock (from Trenkel and Rochet, 2003)

Indicator	Description	Required information	Model	Estimation method
r_i	Intrinsic population growth rate	$N_i(t)$	(1) $N_i(t) = N_i(t-1)\exp(r_i) = \lambda_i N_i(t-1)$	$\log(\hat{N}_i(t)) = \delta_i + r_i t + \omega_{i,t}$ $\omega_{i,t} \sim N(0, \sigma_i^2)$
Z_i	Total mortality	$N_{l,i}(t)$, $t_{0_i} k_i$, L_{∞_i}	(2) Cohort $N_i(t) = N_i(0)\exp(-z_i t)$ $N_{l,i}(t) = \exp\left(\ln(N_i(0) - Z_i\left(t_{0_i} - \frac{1}{k_i}\ln\left(1 - \frac{l_l}{L_{\infty_i}}\right)\right)\right)$	GLM: log-link, quasi-likelihood with var $\propto$ mean$^{\beta_i}$
F_i/Z_i	Exploitation rate	$C_i(t)$, $N_i(t)$, Z_i	(3a) $F_i(t) = C_i(t)/N_i(t)$	(3b) $\hat{F}_i(t) = \hat{C}_i(t)/\hat{N}_i(t)$ $\hat{V}[F_i(t)] = \hat{V}[C_i(t)]/\hat{N}_i(t)^2 + \hat{C}_i(t)^2\,\hat{V}[N_i(t)]/\hat{N}_i(t)^4$ (Kendall and Stuart 1977)
L_{bar_i}	Mean length of catch	$C_{l,i}$	(4) $L_{\text{bar}_i} = \frac{1}{C_i}\sum_{l=1}^{L} C_{l,i}\, l_l$	$\hat{L}_{\text{bar}} = \frac{1}{\hat{C}_i}\sum_{l=1}^{L}\hat{C}_{l,i}\, l_l$ $\hat{V}\left[\hat{L}_{\text{bar}_i}\right] = \hat{L}^2_{\text{bar}_i} \times \left(\frac{\sum_{l=1}^{L} l_l^2\, \hat{V}[\hat{C}_{l,i}]}{\left(\sum_{l=1}^{L} l_l \hat{C}_{l,i}\right)^2} + \frac{\hat{V}[\hat{C}_i]}{\hat{C}_i^2}\right)$
ΔF_i	Change in F to reverse population growth	F_i, Z_i, α_i, λ_i	(5) $\Delta F_i = \exp(\Delta r / e_F - 1)$ $e_F = \frac{F_i}{\lambda_i}\frac{\lambda_i\exp(-Z_i)}{\alpha_i\exp(-Z_i) - \lambda_i(1+\alpha_i)}$ $\lambda_i = \exp(r_i)$	$\hat{e}_F = \frac{\hat{F}_i}{\hat{\lambda}_i}\frac{\hat{\lambda}_i\exp(-\hat{Z}_i)}{\alpha_i\exp(-\hat{Z}_i) - \hat{\lambda}_i(1+\alpha_i)}$ $\hat{\lambda}_i = \exp(\hat{r}_i + V[\hat{r}_i]/2)$ $\hat{\Delta}r = \text{lower CI}(\hat{r}_i)$

Traffic lights

increasing fishing impact, reversal actions to be taken
steady fishing impact, restoration actions to be taken
no fishing impact detected

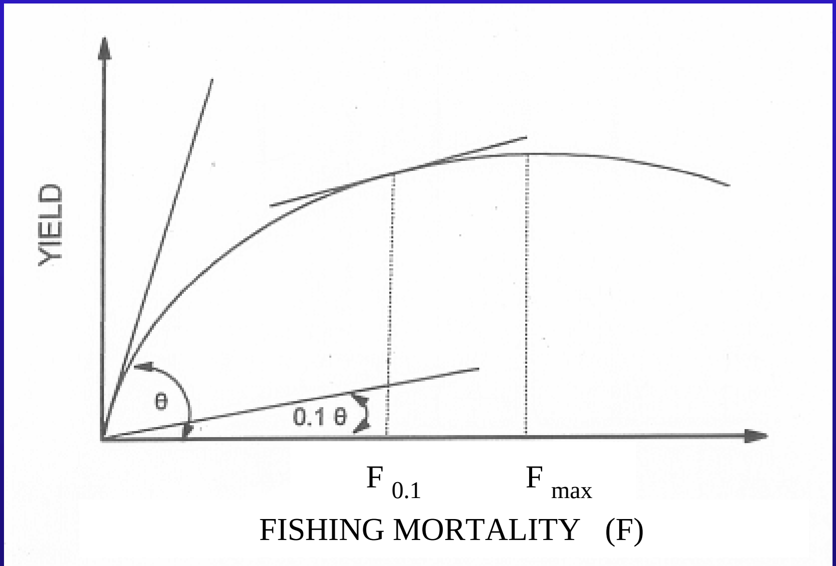
indicator weight

Indicators redundance

Area Period	Total Abundance	Total Biomass	Mean Weight	PropLarge	r	Z	Mean Length
E.Ionian Sea (GSA 20) 1994-2004	↑	→	↓	→	1/46 ↓ 11/46 ↑	1/4 ↑	4/41 ↓ 1/41 ↑
E.Ionian Sea (GSA 20) 1998-2004	↑	→	↓	→	1/47 ↓ 4/47 ↑	1/10 ↑	1/33 ↑
E.Ionian Sea (GSA 20) 2000-2004	→	→	→	→	1/47 ↑	→	2/33 ↑

The proposal from the 2010 demersal WG

- The group adopted $F_{0.1}$ as the Target Reference Point to compare the current fishing mortality and evaluate the exploitation status of the stock. Such approach assumes that $F_{0.1}$ is the best available proxy to Fmsy (Clark, 1991; Die and Caddy, 1997; Gabriel and Mace, 1999; Kell and Fromentin, 2007).



The proposal from the 2010 small pelagics WG

- Both sardine and anchovy are short lived species with rapid dynamics large driven by variable recruitment. Variations in the environment is generally believed to be the main driving force, but the exact environmental factors and the mechanisms by which they influence the stock are not well understood.

- In small pelagics the role of the stock biomass in determining recruitment success is likely minor in most cases., as recruitment obviously requires a spawning stock, a too strong reduction in the spawning stock ,regardless the fishery effect, is bound to have detrimental consequences for the recruitment. Therefore, a stock abundance should be ensured that is sufficient for the stock to respond to favorable environmental conditions once such conditions appear.

- Lacking other evidence, a minimum level of biomass should therefore be to keep the stock above the lowest level where it historically has produced a good recruitment.

…an empirical approach for small pelagics including stock abundance and environmental conditions ….

INDICATORS OF ENVIRON-MENT AND ECOSYSTEM ↓	STOCK CONDITION (based on annual surveys) →		
	HEALTHY STOCK CONDITION	BIOMASS BELOW Bpr	BIOMASS BELOW Blim
habitat/environ-mental conditions satisfactory	May increase capacity	maintain capacity constant	Close the fishery in this subarea
Evidence of deteriorating productivity	maintain capacity constant	Seek to reduce capacity or days fished	Close the fishery in this subarea
Habitat/ environ mental conditions unsatisfactory	Seek to reduce capacity or days fished	Close the fishery in this subarea	Close the fishery in this subarea

Criteria for choosing suitable stock assessment approaches and BRPs for the Mediterranean and Black Sea

- **Realistic**
- **Simple**
- **Robust**
- **Availability of data needed**
- **Allows uncertainty considerations**
- **Easiness of translating in management advice**
- **Is there some approach superior?**

How can we improve the choice and use of BRPs to make more transparent and useful our assessment?

- The technical decision (F_{MSY}, Z_{MBP}, F_{max}, $F_{0.1}$, SPR $_{40\%,}$ Z_{med} or F_{med} for demersals and E0.4 and Blim for small pelagics) should be discussed and agreed at higher instances within GFCM.
- Improve the critical interface between scientists and managers receiving research advice, in order to identify the most proper RP in function of the management objectives.