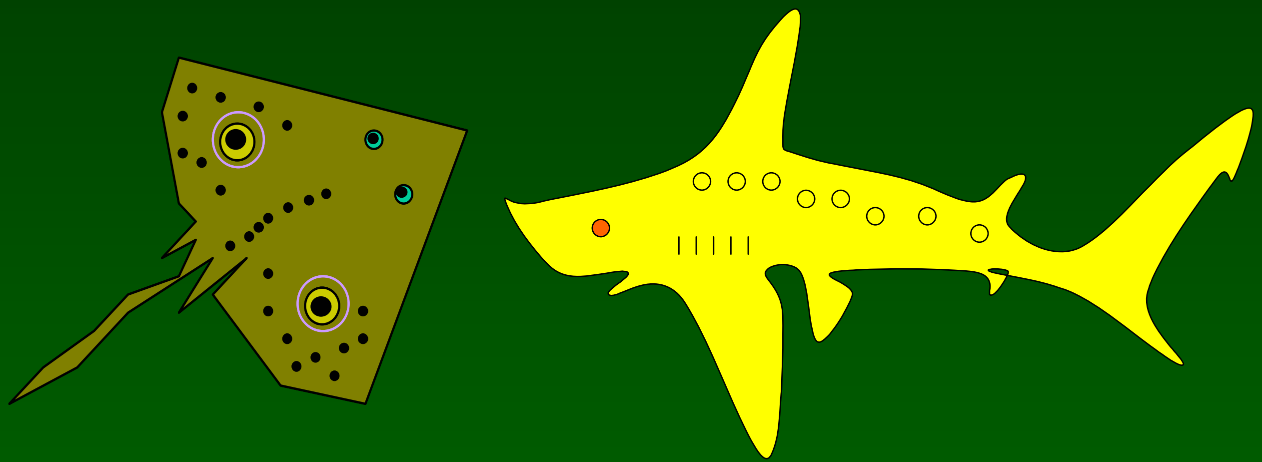
Suitable methods for stock assessment of chondrichtyans



Selection of suitable approaches for situations of limited data

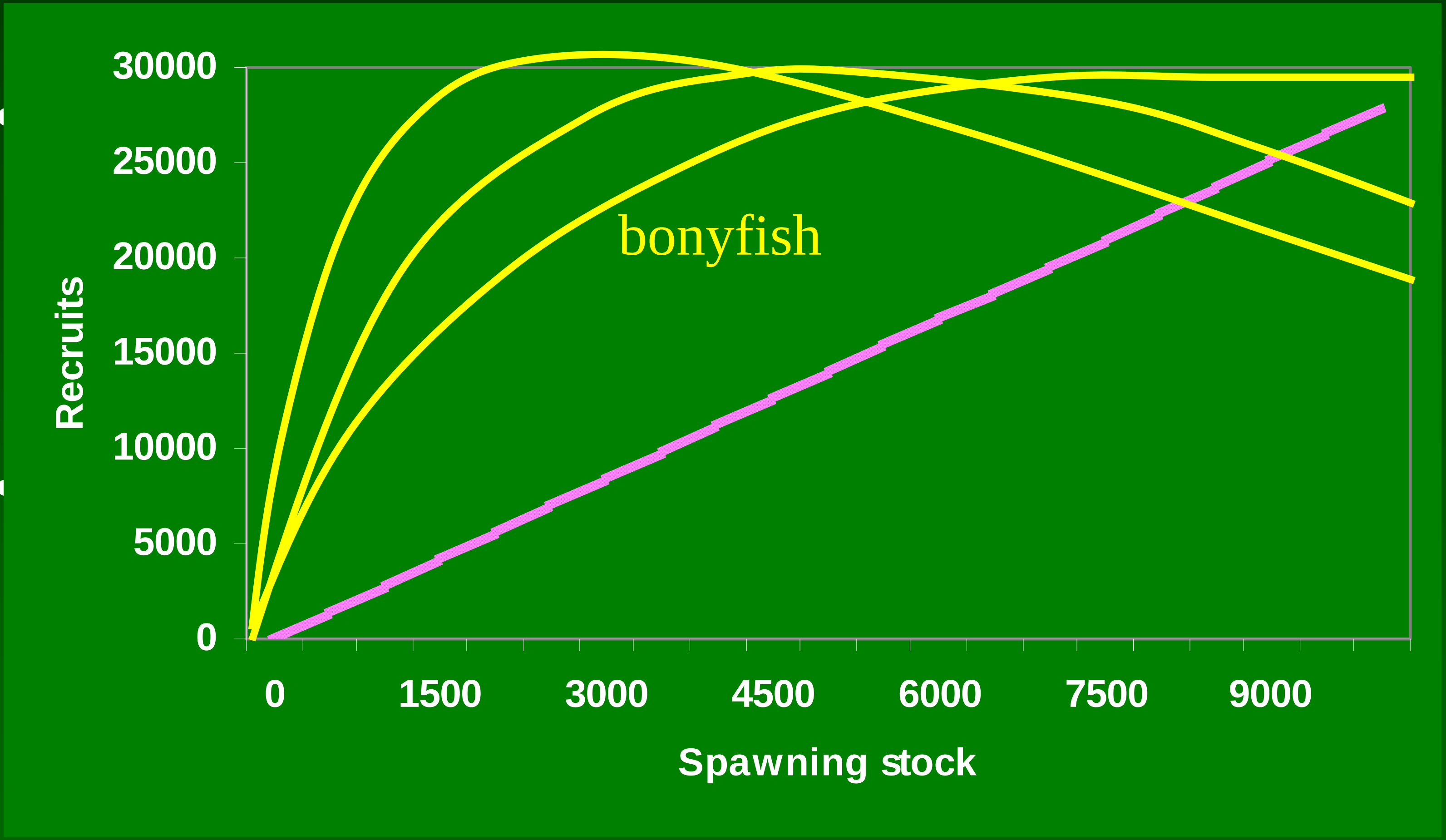
Main biological features

- Slow growing
- Relatively long lived
- Late age of maturity
- Reduced fecundity
- …but good survival rate of eggs
- Low natural mortality rates
- Direct relationship between spawning stock and recruits

Productivity and resilience

- Linked with natural history traits
- General low productivity
- Smaller sized species somewhat more productive

Stock and recruitment



RESILIENCE

“The ability of a system to utilize, profit from, and absorb natural variation”(Hilborn & Walters, 1996)

“A system with a large region of desirable behavior is called resilient”. Man reduces this region…

- **Age and size at maturity and adult size/longevity more important predictors of resilience to fishing pressure than fecundity or eggs survival**
- **Large ray and shark species with late maturation more vulnerable to heavy fishing pressure *(Walker & Hislop, 1998, Frisk at al, 2001,2002)***

What is overfishing?

- Removing too many fish
- Applying a too high fishing rate
- ***Result:***
- The stock cannot produce enough recruits to maintain itself at a productive level.

Types of Overfishing

- **Growth overfishing- related to the size and age of fish**
- **Recruitment overfishing- related to the production of new recruits**

The need of Biological Reference Points

- *Key fishing rates or biomass levels that are related to the maximum potential of a stock*
- A ***fishing rate (F)*** that produce the highest catches or spawning potential
- A ***biomass*** level that produces the highest catches

Target

Management targets are:

- *A level of F that gets you to a goal.*
- An F target gets you to a desired place (i.e.maximum yields, max.revenues,etc)

- *A level of biomass is a goal.*
- A biomass target is a desired place (i.e. a biomass level that represents some fraction of the pristine biomass)

Limits

Limits are:

- F's you shouldn't exceed, a biomass you shouldn't go below
- A key reference point value like F_{msy}, $F\%_{SSBv}$ or B_{msy}

Why does it matter?
(overfishing)

- Causes the stock to decline to a less productive state
- Reduces future catches and earnings
- Removes fish too early in their life
- Reduces recruitment, in many cases dramatically
- Does not guarantee sustainability

What is in general done for the assessment of the chondrichtyans status?

•Surplus Production models (SPM)

- **Excellent cost/benefit ratio**
- **Data requirements modest**
- **SPM can yield critical information for assessment and management:**
- **B_o,B_{curr}, level of depletion of the population, MSY, f_{MSY}**
- **Projections under different scenarios (yield, effort), and to evaluate outcomes of each scenario**

•Surplus Production models (SPM)

- but….
- They do not include stock structure and its changes
- They do not incorporate time delays (very important for elasmobranchs)
- Traditional versions assume equilibrium
- Need of contrast in levels of fishing pressure along time series

•Yield per Recruit

- Simple approach
- Does not require time series
- It tell us if we are exploiting fish at the right age/size and with the right intensity
- Are easy to translate into direct management recommendations (changes in mesh size or regulation of fishing effort)

•Yield per Recruit

- But…
- Assume equilibrium
- Not dynamic (no time variable)
- Do not incorporate density-dependent processes like S/R relationships
- Assume constant growth and mortality
- It may predict unrealistic yields at infinite effort
- The real magnitude of catch cannot be known

Other used approaches

- VPA
- Catch-at-age and other stock syntesis
- Leslie matrix
- PSA
- others…

What can **WE** do in the Med?

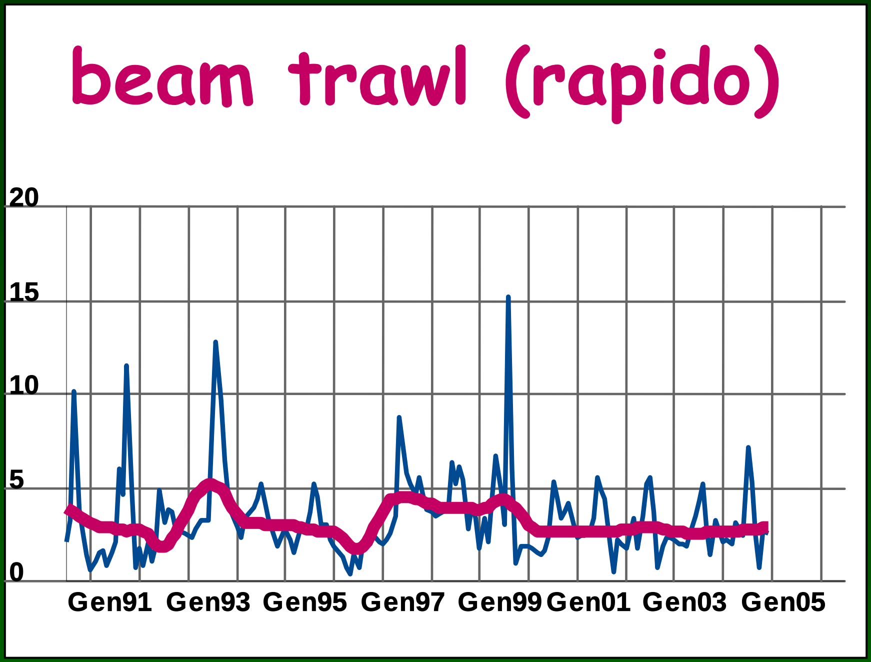
•Sources: data can derive from direct (fisheries independent) and indirect (fisheries dependent) methods

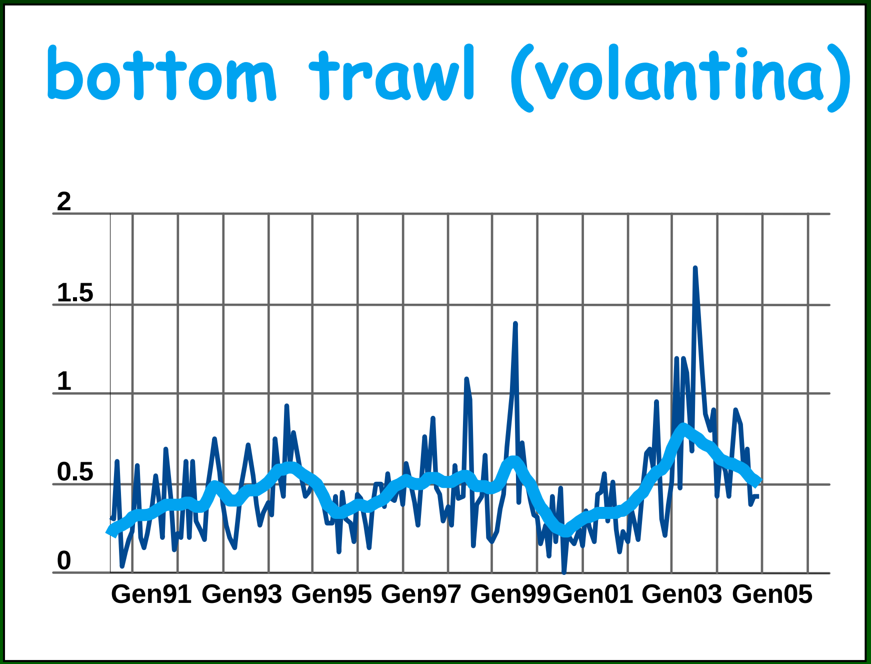
- **Trawl surveys available data (MEDITS, etc)**
- **Data bases (MEDLEM, etc.)**
- Biological (growth, maturity, etc)
- Catch rates (catch per unit of area or time)
- Demography (age/size structure at sea)

The modest number of individuals caugh by species makes some times unsuitable the analysis of time series and the application of many other approaches of stock assessment

ANALISIS OF TRENDS

Trend in landings: *R. asterias*





Analysis of time series of LPUE (kg/h) from July 1990 to December 2004 (Tramo-Seat (ARIMA model);DEMETRA 2.04 (Eurostat, 2002)) **show a quite stable situation of the captures**

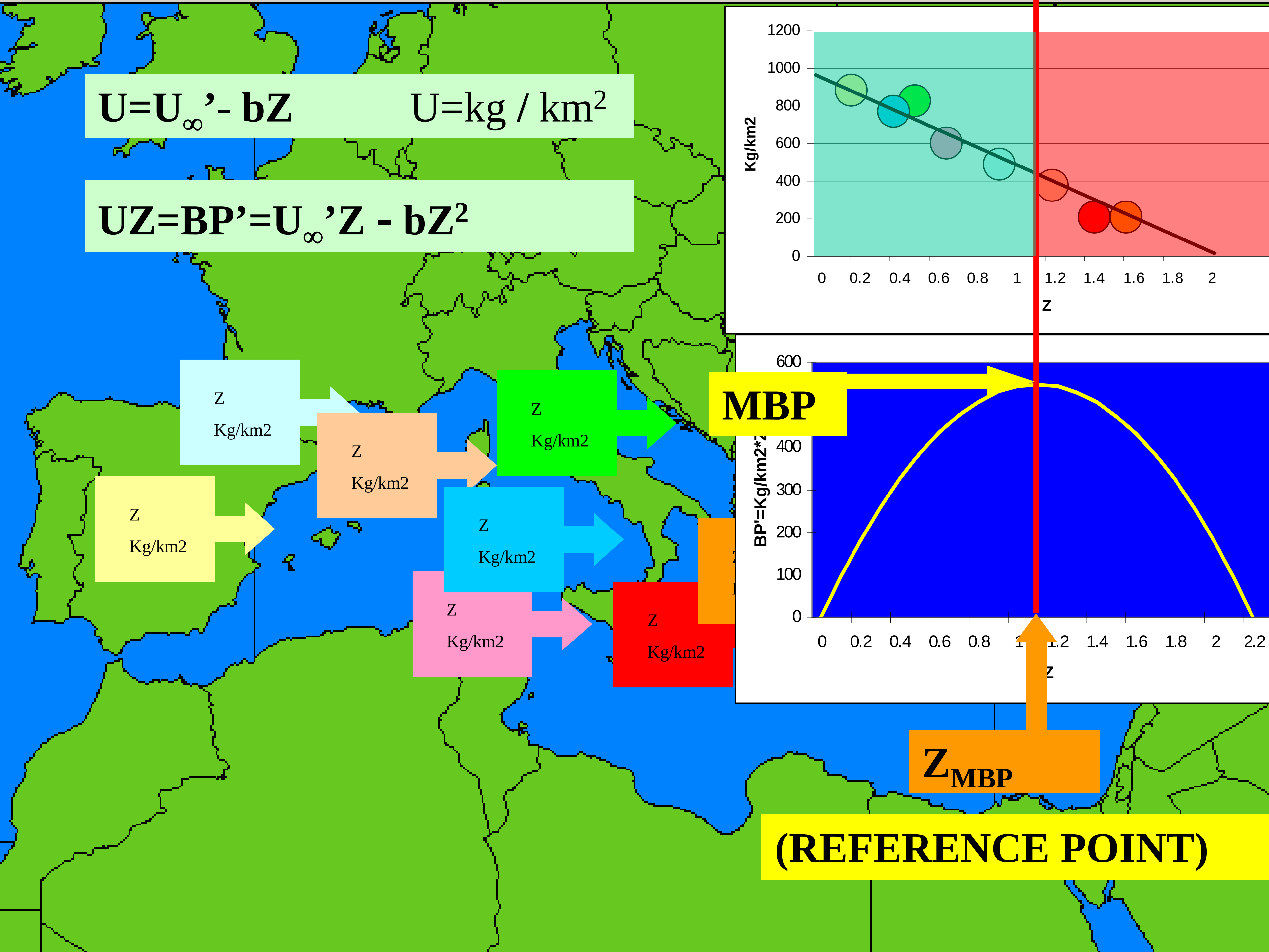
Some attempts of stock assessement with available data

- Surplus Production models
- **Composite model**

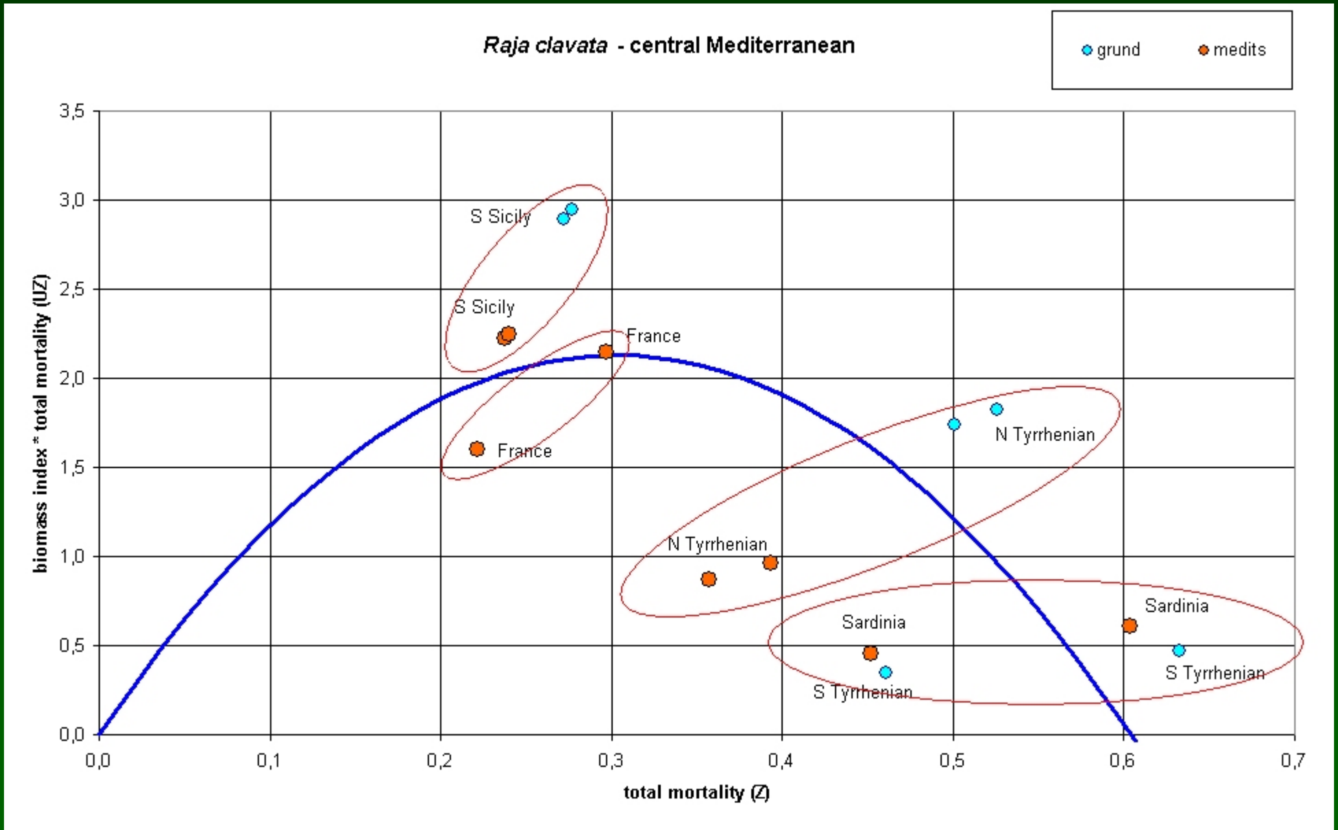
- Composite models use spatial information proceeding from sub-areas exploited at different rates
- similar productivity and evolution under different levels of fishing pressure are assumed
- The change from a time to space-based data set allows the utilization of production models even in the case long data series on catch and effort are not available
- The results are not affected by most of the problems that characterize the traditional versions of surplus production models.

Composite model

- The approach is used for the definition of a sustainable level of fishing pressure
- Also useful for a preliminary assessment of the current status of exploitation in different fishing grounds exploited with different rates
- In this case, total mortality rate is used as a direct index of fishing mortality
- Considering that Z includes both, removals of fishing activity and deaths due to natural causes, the model allows the estimation of the so-called Maximum Biological Production (MBP)


U=U∞'- bZ
U=kg / km2
UZ=BP'=U∞'Z - bZ2
Z
Kg/km2
Z
Kg/km2
Z
Kg/km2
Z
Kg/km2
Z
Kg/km2
Z
Kg/km2
Z
Kg/km2
Kg/km2
1200
1000
800
600
400
200
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
Z
MBP
600
400
300
200
100
0
0 0.2 0.4 0.6 0.8 1.2 1.4 1.6 1.8 2 2.2
Z
ZMBP
(REFERENCE POINT)

Raja clavata



Mean value in each area by sex

Non equilibrium biomass dynamic Models

Traditional: Time series of index of abundance and effort

$$B_{t+1} = B_t + rB_t(1-(B_t / k)) - qfB_t$$

With trawl surveys NO data on effort

As $qfBt = Y$, *catch in weight* (Y_t) *can be substituted by the classic Baranov (1918) catch equation*

$$Y=(F/Z)\,B(1-\exp(-Zt))$$

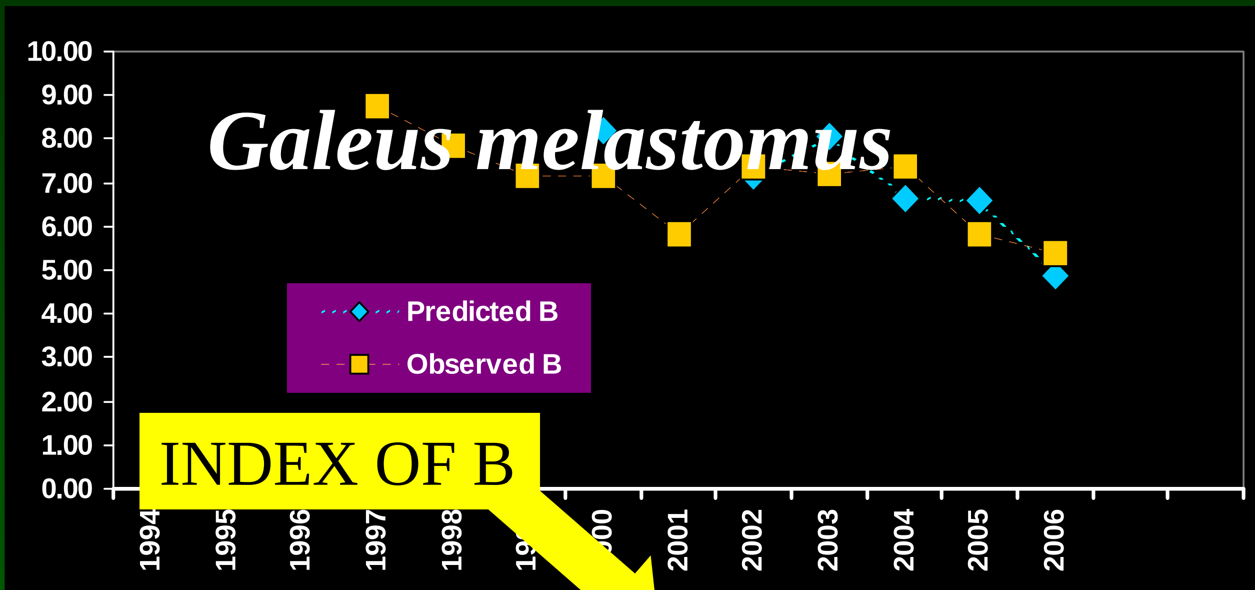
and then the following equation is obtained:

$$B_{t+1} = B_t + rB_t(1-(B_t / k)) - (F/Z)\,B_t(1-\exp(-Zt))$$

Non equilibrium surplus production model

$$B_{t+1} = B_t + rB_t(1-(B_t / k)) - (F/Z) B_t(1-\exp(-Z_t))$$

Zmbp =	0.624
Zcurr =	1.305
r=	0.64822
K'=	46.3774



Time	Observed Z	Predicted B	Observed B
1994			[illegible]
1995			[illegible]
1996			[illegible]
1997			8.74
1998			7.85
1999	0.862		7.14
2000	0.711	8.18	7.17
2001	0.836		5.80
2002	1.185	7.14	7.36
2003	1.534	8.06	7.21
2004	1.56	6.64	7.35
2005	1.428	6.59	5.82
2006	0.928	4.88	5.38

MINIMIZATION OF RESIDUALS

Need of contrast!!!

Other attempt of stock assessement with available data

•Yield per recruit

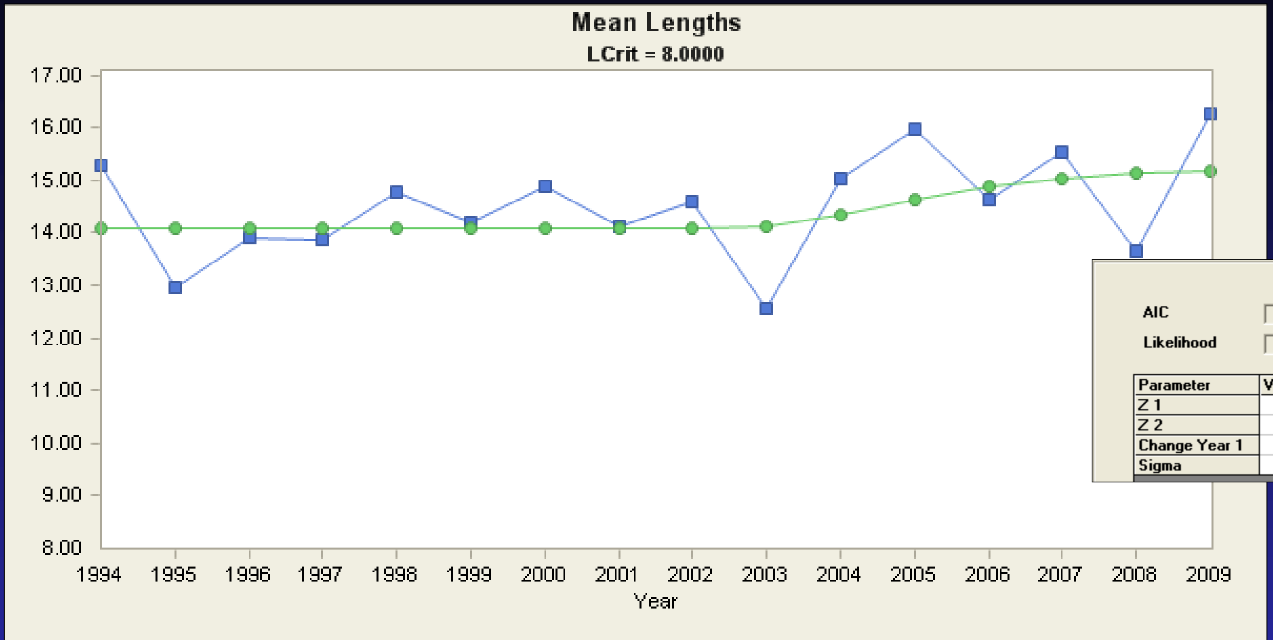
A Beverton & Holt like model can be constructed.

- **Common biological parameters (considered representative for the species for the whole area) may be used**
- **Y/R and S/R curves can be defined**
- **F_{max}, $F_{0.1}$ and $F_{30\%SSB}$ can be estimated**
- **F_{curr} is compared with the above Reference Points**

Estimates of Z

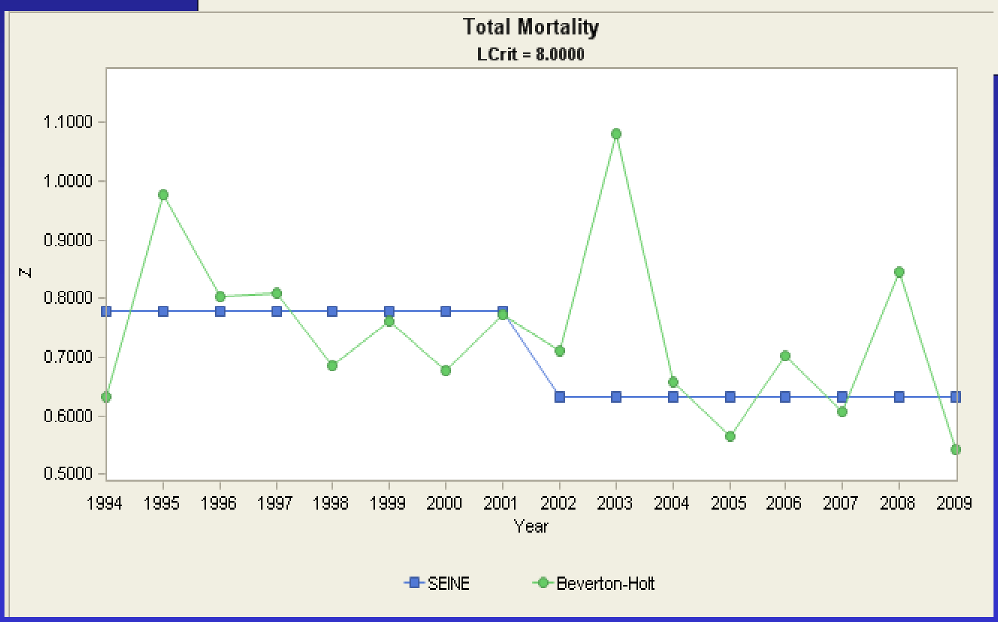
Classical catch curves (some assumptions…)

- Data necessary for Z estimation may derive from commercial catch on size composition and abundance indices . But if data are not complete?
- SEINE software (**Survival Estimation in non-equilibrium situations**) (Gedamke and Hoenig, 2006) can be used for the estimation of Z, using weighted **information of mean size of catch, size of full capture and growth parameters**. The **transitional behavior** of the mean length statistic is derived for use in non-equilibrium conditions. This new non-equilibrium estimator allows a change in mortality to be characterized reliably several years faster than would occur with the use of the Beverton–Holt estimator



AIC	131.2488
Likelihood	61.6244

Parameter	Value	STD Deviation
Z 1	0.77772271	0.039267
Z 2	0.63343090	0.055421
Change Year 1	2002.813	0.855640
Sigma	11.38829052	2.013200



Date_of_Run: 21_Apr_2010

Time_of_Run: 09:37

Number of Breaks = 1

First Year in Data = 1994

Number of Years = 16

Number of Parameters = 4

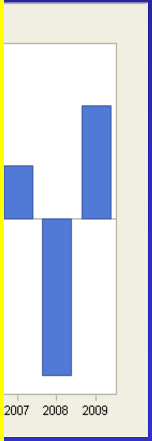
AIC = 131.2488

Negative Log Likelihood = 61.6244

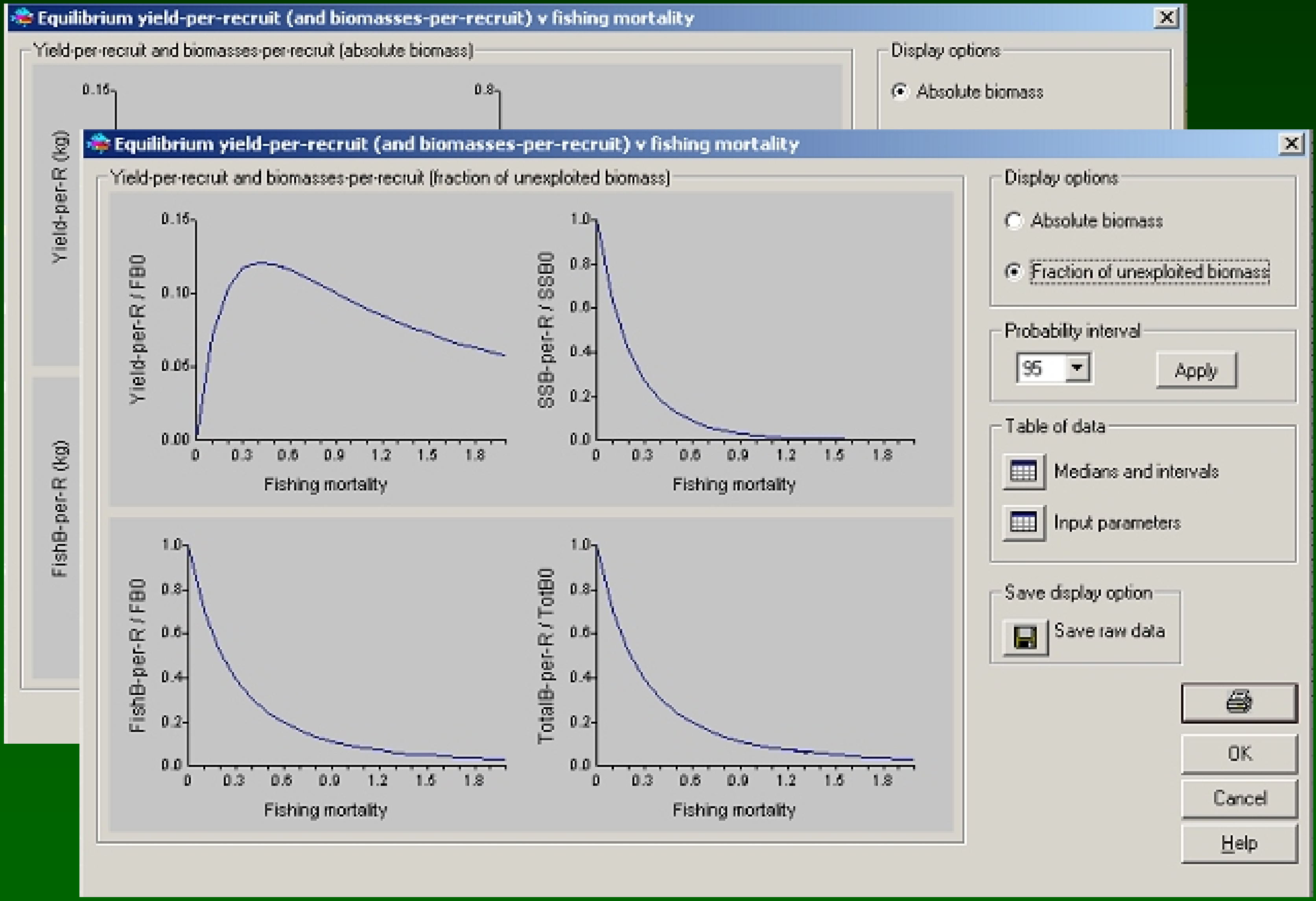
VB K = 0.1180

VB Linf = 54.3000

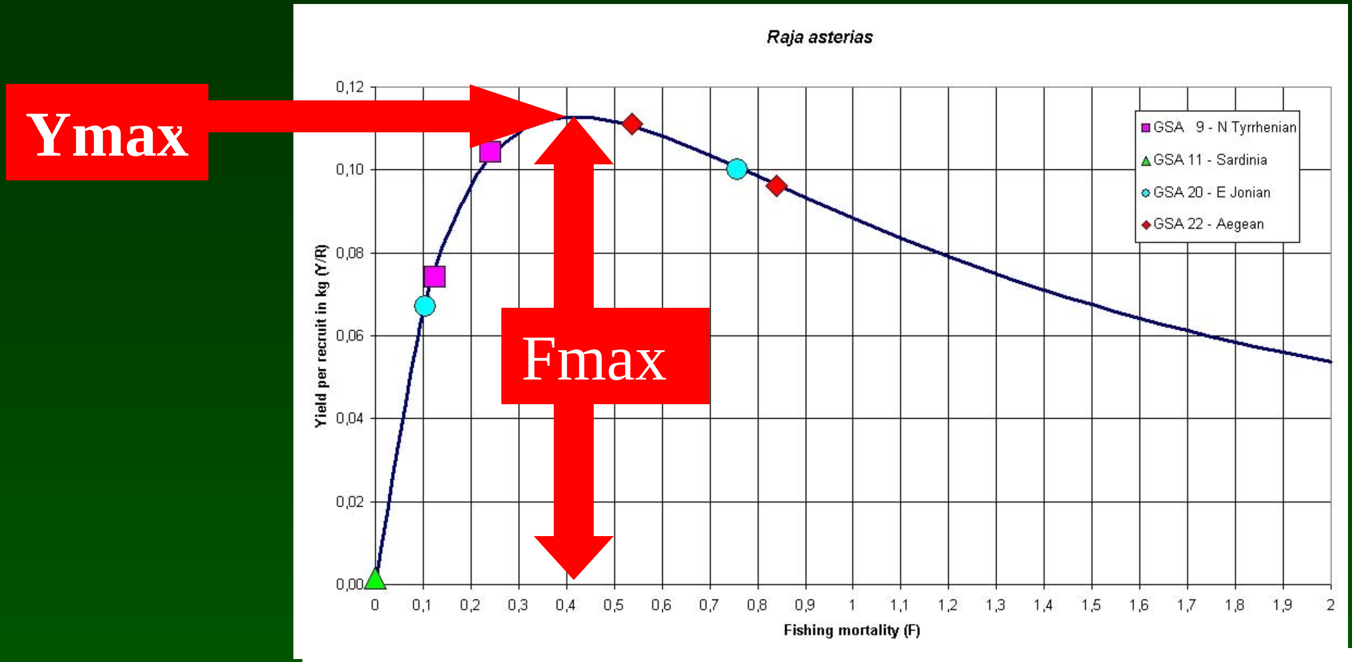
L Crit = 8.0000

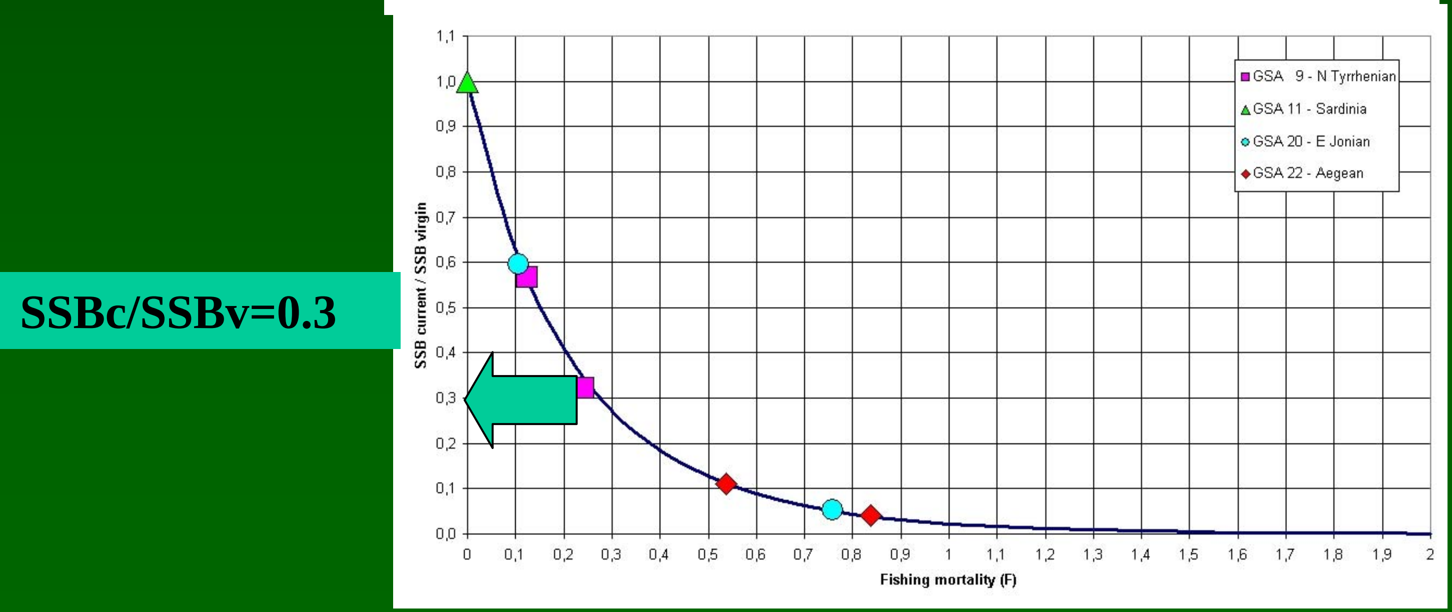


Y/R, B/R and SSB (absolute and relative)



Raja asterias





PSA

- PSA (Productivity and Susceptibility Analysis) developed by Stobutzki et al (2001)
- a semi-quantitative approach considered very useful for examining the vulnerability of stocks
- Used by several organizations and working groups as an approach for determining **vulnerability and risk** of driving stocks to unsustainable levels.

The two elements fundamental for determining vulnerability

- stock **productivity** mainly dependent on life-history characteristics. Related with the capacity of the stock to fast recover when is at low values of abundance
- stock **susceptibility**, that is the potential of a stock to be negatively impacted by a fishery

PSA assumes that the species in a fishery will be at risk if they are characterised by a **low productivity**, that implies long recovery times and/or if they are **very susceptible** (they are highly exposed) to the fishing activity

Several units of analysis, that include indicators linked to productivity and susceptibility are used

The Productivity attributes

- **The intrinsic rate of population growth r** is the maximum population growth that would occur in the absence of fishing.
- **Maximum age** is linked to the natural mortality rate M, because M is negatively correlated with maximum age.
- **Maximum size** is correlated with productivity, because large fish have in general lower levels of productivity.
- **von Bertalanffy growth coefficient K** measures the time a fish needs to reach its maximum size. In general, long-lived species have low K and also are characterised by a lower productivity
- **Natural mortality M.** Natural mortality rate defines the population productivity because the stocks with high M need of higher levels of production for maintain adequate levels of abundance.
- **Fecundity** is the number of eggs that a female produce in certain period. Musik (1999) suggested fecundity be always measured at the age of first maturity.

The Productivity attributes(2)

- **Breeding strategy** indicates the level of mortality during the first life phases than is related to the way eggs and larvae are placed in the water column, the time (if any) of parental protection of eggs or larvae, the time of gestation.
- **Recruitment pattern** is related to the frequency of recruitment success.
- **Age at maturity** is in general related with the maximum age and long-lived low-productive species in general show a older age of maturity.
- **Mean trophic level** can be a useful information for inferring stock productivity. Major productivity is in general observed for the species that are at lower trophic levels in the community.

The Susceptibility attributes

- **Management strategy.** The susceptibility of a stock to be hardly fished will depend on the existence of control rules. Stocks managed by using some effort or catch limitation is expected will have a low susceptibility to overfishing.
- **Area overlapping** measures the level of spatial overlap between the distribution of the stock and the distribution of the fishing effort. A major overlap makes the stock more susceptible to be impacted by fishing activity.
- **Spatial concentration** supplies information on the geographic distribution pattern of a stock. A highly aggregated stock is more susceptible than other with a very scattered spatial distribution.
- **Vertical overlapping** measures the degree of overlapping by comparing the vertical distribution of the stock along the water column with the depth in which the fishing gear operates.
- **Fishing mortality rate** (in relation to M). When estimates of fishing and natural mortality rates are available, it is possible to define which portion of the production is removed by each one of them. Here a threshold value for F/M=1 is used as a conservative reference value.

The Susceptibility attributes(2)

- **Surviving fraction of spawners biomass.** The rate between the current stock biomass and the expected level for the unfished stock is used as an indicator of susceptibility to fishing activity. It is expected that the value of this rate will decrease as fishing effort increase.
- **Seasonal migrations.** Movements of exit or entry from the fishery area affect the level of overlapping between the stock and the operational area of the fishery and the “encounterability”.
- **Schooling aggregation** addresses behavioural features that may affect catchability, but also changes in the area of distribution due to changes in the population size.
- **Morphology affecting capture.** The efficiency of capture of a gear may be conditioned by the morphological characteristics of a species and the individual size. The inclusion of this attribute considers the portion of the demographic composition of the population that is vulnerable to the fishing gear in use.
- **Survival after release.** The survival of released individuals may vary by species, utilised fishing gear, depth, affecting the susceptibility of the stock.

PRODUCTIVITY ATTRIBUTES

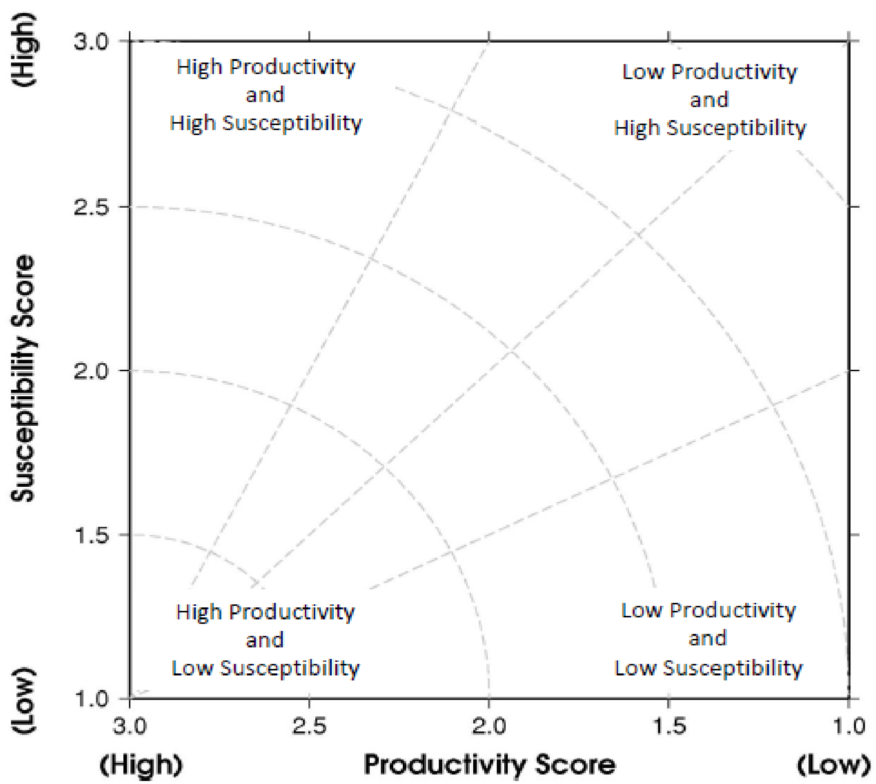
Productivity Attributes	High (3)	Moderate (2)	Low (1)
r	>0.5	0.5-0.16 (mid-pint 0.10)	<0.16
Maximum Age	< 10 years	10 - 30 years (mid-point 20)	> 30 years
Maximum Size	< 60 cm	60-150 cm (mid-point 105)	> 150 cm
von Bertalanffy Growth Coefficient (k)	> 0.25	0.15-0.25 (mid-point 0.20)	< 0.15
Estimated Natural Mortality	> 0.40	0.20-0.40 (mid-point 0.30)	< 0.20
Measured Fecundity	> 10e4	10e2-10e3	< 10e2
Breeding Strategy	0	between 1 and 3	?4
Recruitment Pattern	highly frequent recruitment success (> 75% of year classes are successful)	moderately frequent recruitment success (between 10% and 75% of year classes are successful)	infrequent recruitment success (< 10% of year classes are successful)
Age at Maturity	< 2 years	2-4 years (mid-point 3.0)	> 4 years
Mean Trophic Level	<2.5	2.5-3.5 (mid-point 3)	>3.5

SUSCEPTIBILITY ATTRIBUTES

Susceptibility Attributes	Low (1)	Moderate (2)	High (3)
Management Strategy	Targeted stocks have catch limits and proactive accountability measures; Non-target stocks are closely monitored.	Targeted stocks have catch limits and reactive accountability measures	Targeted stocks do not have catch limits or accountability measures; Non-target stocks are not closely monitored.
Areal Overlap	< 25% of stock occurs in the area fished	Between 25% and 50% of the stock occurs in the area fished	> 50% of stock occurs in the area fished
Geographic Concentration	stock is distributed in > 50% of its total range	stock is distributed in 25% to 50% of its total range	stock is distributed in < 25% of its total range
Vertical Overlap	< 25% of stock occurs in the depths fished	Between 25% and 50% of the stock occurs in the depths fished	> 50% of stock occurs in the depths fished
Fishing rate relative to M	<0.5	0.5 - 1.0	>1
Biomass of Spawners (SSB) or other proxies	B is > 40% of B0 (or maximum observed from time series of biomass estimates)	B is between 25% and 40% of B0 (or maximum observed from time series of biomass estimates)	B is < 25% of B0 (or maximum observed from time series of biomass estimates)
Seasonal Migrations	Seasonal migrations decrease overlap with the fishery	Seasonal migrations do not substantially affect the overlap with the fishery	Seasonal migrations increase overlap with the fishery
Schooling/Aggregation and Other Behavioral Responses	Behavioral responses decrease the catchability of the gear	Behavioral responses do not substantially affect the catchability of the gear	Behavioral responses increase the catchability of the gear [i.e., hyperstability of CPUE with schooling behavior]
Morphology Affecting Capture	Species shows low selectivity to the fishing gear.	Species shows moderate selectivity to the fishing gear.	Species shows high selectivity to the fishing gear.
Survival After Capture and Release	Probability of survival > 67%	33% < probability of survival < 67%	Probability of survival < 33%
Desirability/Value of the Fishery	stock is not highly valued or desired by the fishery	stock is moderately valued or desired by the fishery	stock is highly valued or desired by the fishery
Fishery Impact to EFH or Habitat in General for Non-targets	Adverse effects absent, minimal or temporary	Adverse effects more than minimal or temporary but are mitigated	Adverse effects more than minimal or temporary and are not mitigated

Assessment of vulnerability

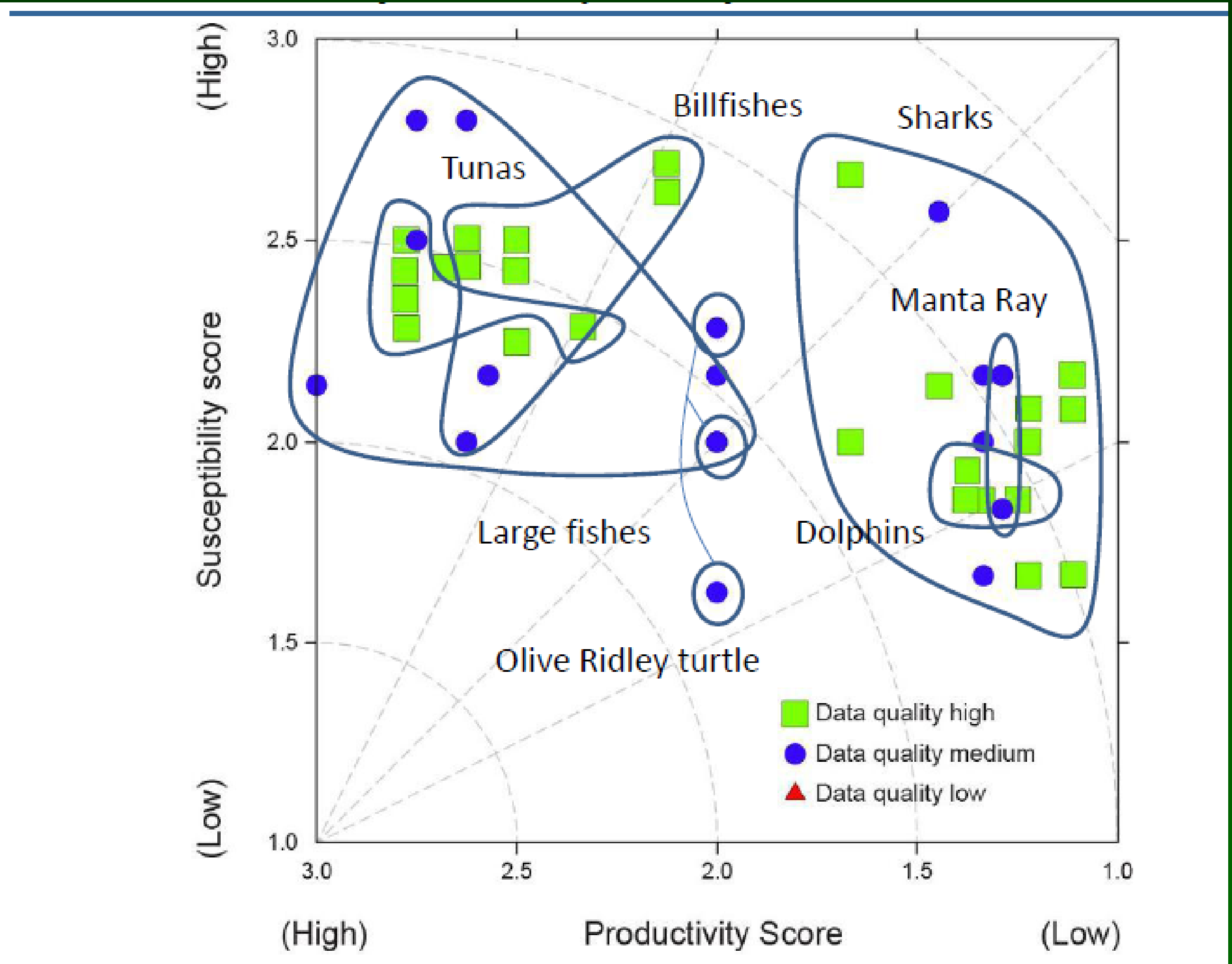
PSA scatter plot



Vulnerability is measured as Euclidian distance from plot origin

$$v = \sqrt{(p-3)^2 + (s-1)^2}$$

PSA


Billfishes
Sharks
Tunas
Manta Ray
Large fishes
Dolphins
Olive Ridley turtle
Data quality high
Data quality medium
Data quality low
(High)
Susceptibility score
(Low)
3.0
2.5
2.0
1.5
1.0
3.0
2.5
2.0
1.5
1.0
(High)
Productivity Score
(Low)

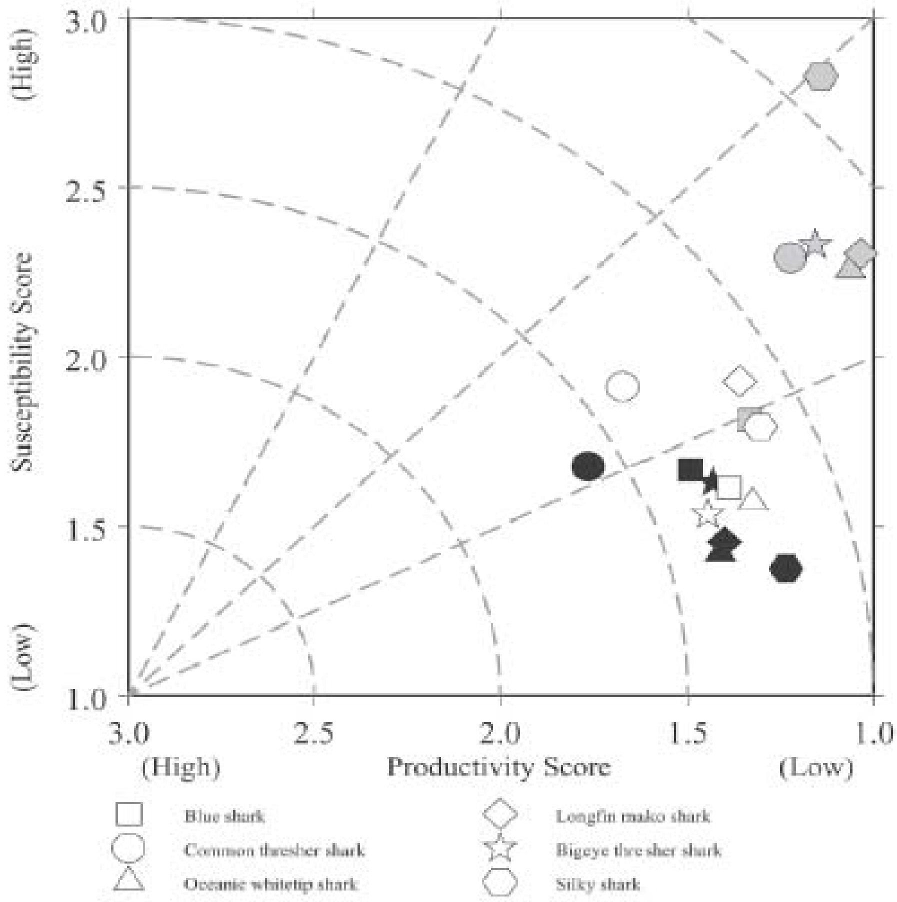


Figure 2

Comparison of vulnerabilities among common shark species in the highly migratory Atlantic shark complexes (gray), Hawaii-based pelagic longline—tuna sector (white), and Hawaii-based pelagic longline—swordfish sector (black).

(example of utilization of PSA)

Aquat. Living Resour. 23 (2010) 25-34

Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries

Enric Cortés[1], Freddy Arocha[2], Lawrence Beerkircher[3], Felipe Carvalho[4], Andrés Domingo[5], Michelle Heupel[6], Hannes Holtzhausen[7], Miguel N. Santos[8], Marta Ribera[1] and Colin Simpfendorfer[9]

Life tables

Stock assessment: *Raja asterias*

Life history table

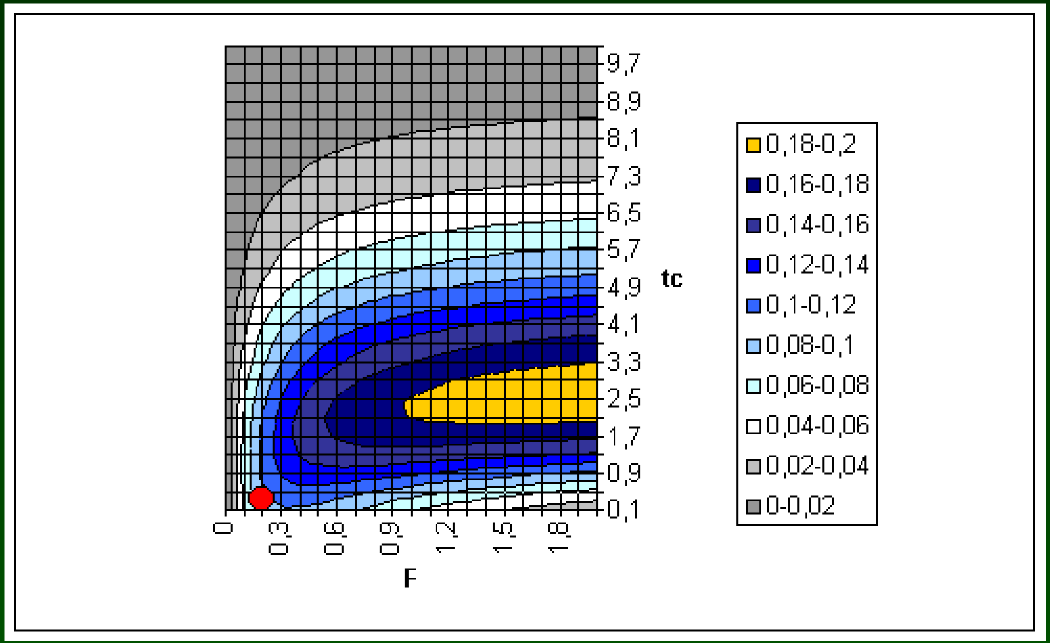
Age (t)	proportion surviving (l_t)	Female pups (m_t)	Reproductive rate ($l_{t+1}m_t$)	$l_{t+1}m_t t$	e^{-rt}	$l_{t+1}m_t e^{-rt}$	
0	1	0	0	0	1	0	
1	0.570638	0	0	0	0.78813617	0	
2	0.325628	0	0	0	0.62115862	0	
3	0.185816	0	0	0	0.48955758	0	
4	0.106034	17	1.02861511	4.11446044	0.38583803	0.39687883	
5	0.060507	27	0.914977991	4.57488996	0.30409291	0.27823832	
6	0.034527	34	0.662010453	3.97206272	0.23966662	0.15866181	
7	0.019703	39	0.435108262	3.04575784	0.18888993	0.08218757	
8	0.011243	46	0.295124315	2.36099452	0.14887099	0.04393545	
9	0.006416	50	0.183053468	1.64748121	0.11733061	0.02147778	
10	0.003661	55	0.201358815	2.01358815	0.0924725	0.01862015	
			3.720248415	21.7292348		1.00	sommatory
			R_0	5.84080212	0.22493322		MUST BE =1
			Net Reprod.rate	G	r_m	2.91135068	
				Generation lenght		t_{x2}	

M=	0.561
r=	0.2381

Raja asterias

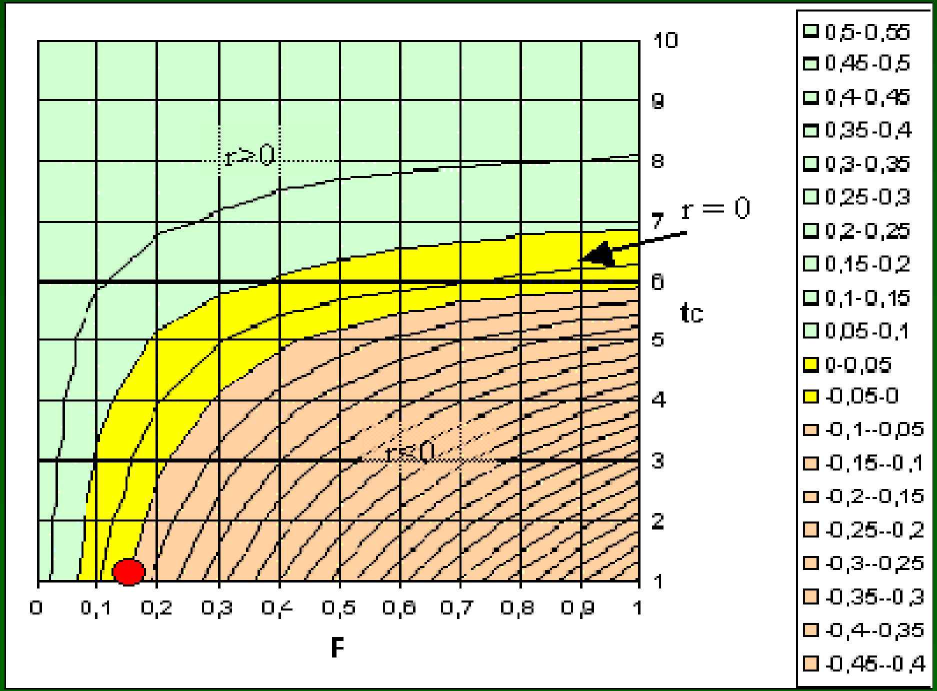
Fecundity at age

Surviving fractions by age



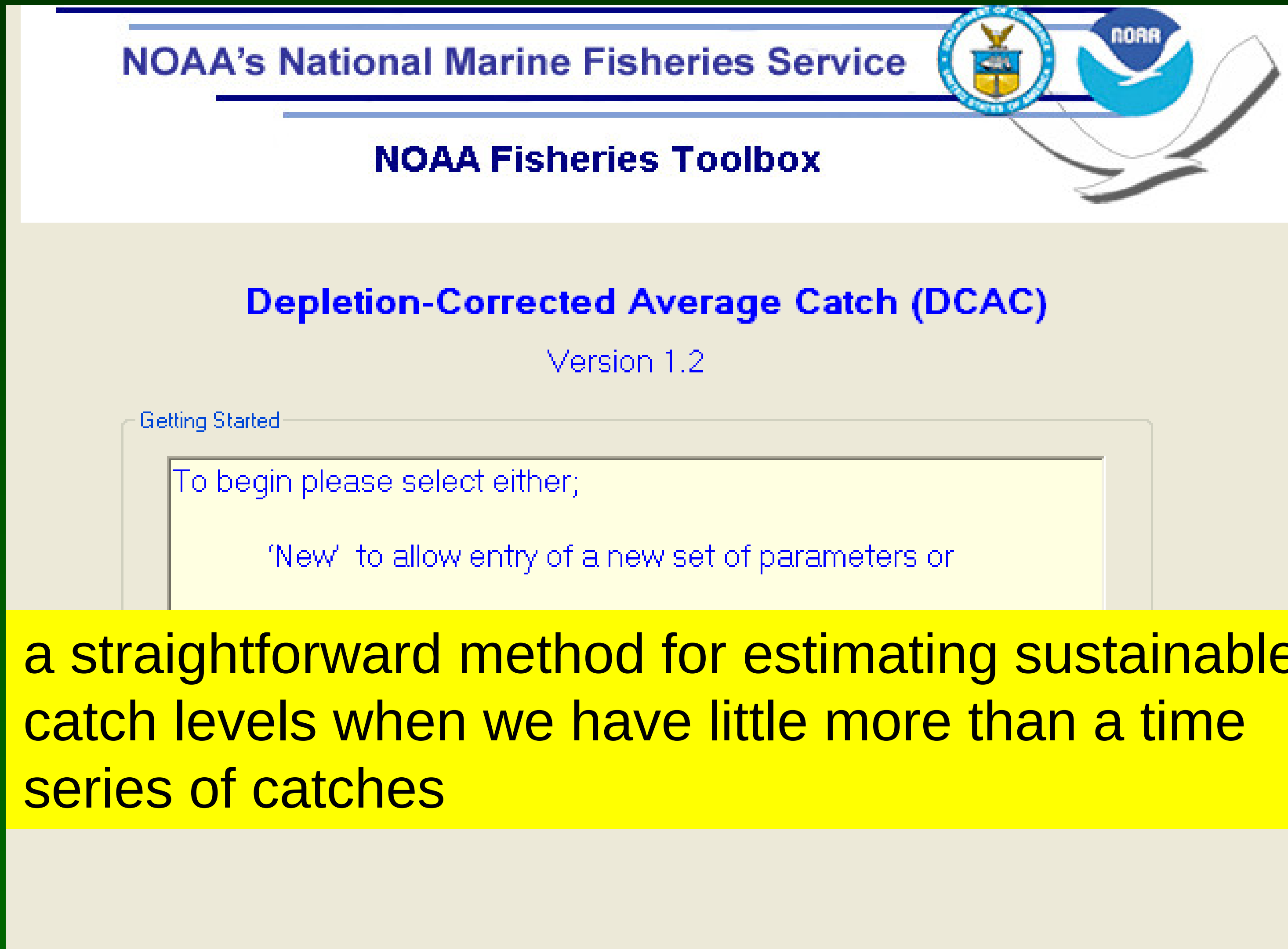
Contours of yield per recruit

Raja asterias



Contour plots constructed displaying the values of *r* corresponding to different combinations of *tc* and F.

DCAC

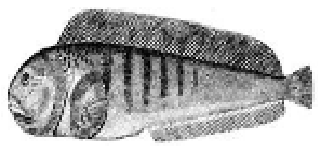


a straightforward method for estimating sustainable catch levels when we have little more than a time series of catches

NOAA's National Marine Fisheries Service

NOAA Fisheries Toolbox

Depletion Corrected Average Catch (DCAC)



| About | Downloads | References | Version History |

About

Version 1.2 *(January 2009)* *Research Model*

The **Depletion-Corrected Average Catch** is a method for estimating sustainable yields for data-poor fisheries. Based on the idea that the average catch has been sustainable if abundance has not changed, DCAC makes a correction to that average if abundance has increased or decreased (which may be the subject of an educated guess based on subjective impressions). The magnitude of the correction depends on the approximate natural mortality rate, which should be about 0.2 or smaller to apply this model. Uncertainty is recognized in all of the parameters in the model, and is reflected in the output probability distribution.

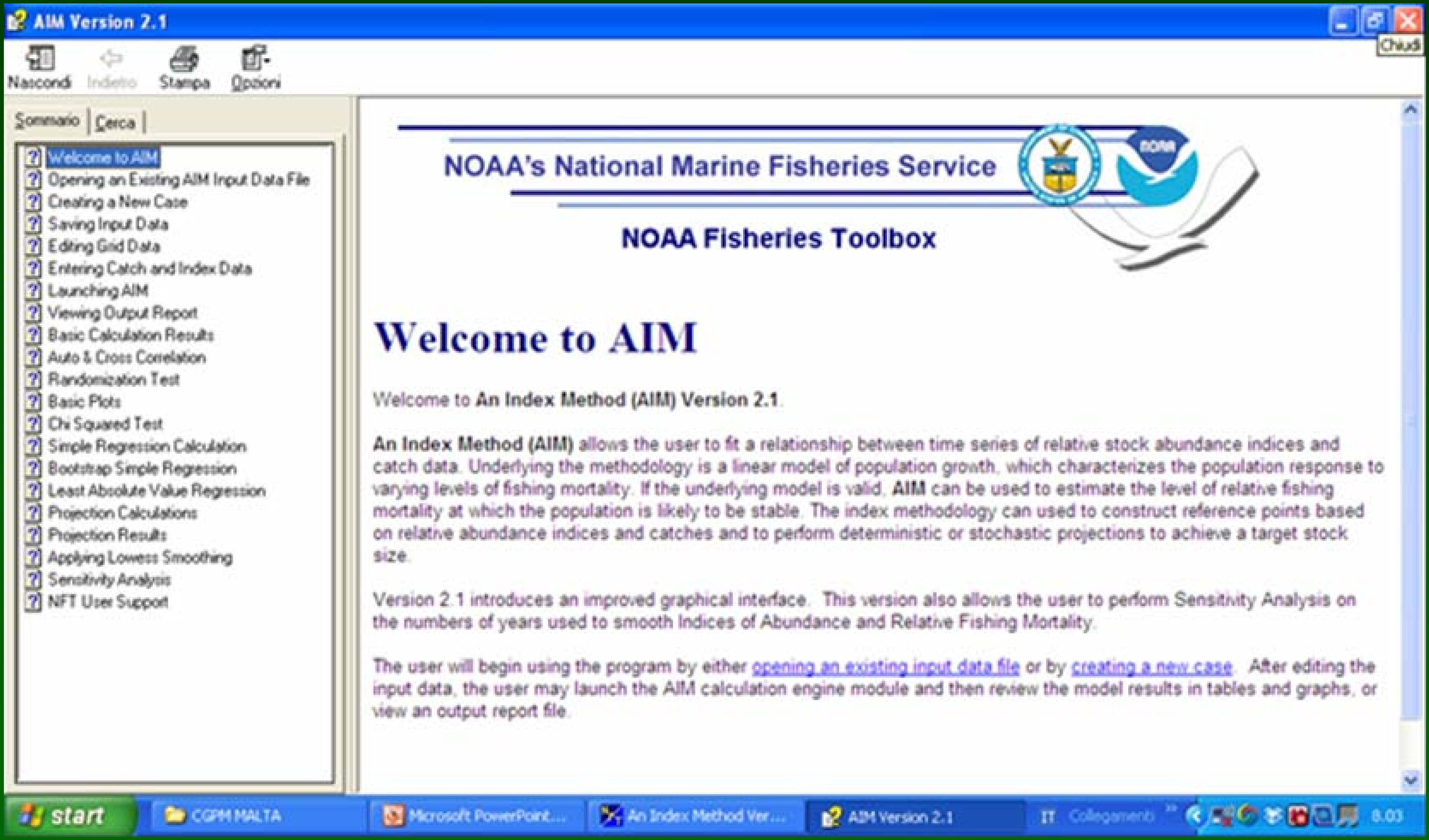
Back to Top

References

Alverson, D., and W. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean – an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish Res. Board Can. 26:1985-2001.

Deriso, R. 1982. Relationship of fishing mortality to natural mortality and growth at the level of maximum sustainable yield. Can. J. Fish. Aquat. Sci. 39:1054-1-58.

AIM method using an index of F



Run Summary | Plots

```
Depletion Corrected Average Catch Model Version 1.1.1
(Calculation Engine)

Case Description: rossetto

Number of Years         =          18
Random Number Seed      =    24218750
Number of Iterations    =       10000

                                  Value        STD Deviation

Sum of Catch            =        367.5619
Natural Mortality       =          3.0000           0.0000
FMSY to M               =          1.0000           0.2000
Depletion Delta         =          0.0800           0.1000

Uncorrected Avg. Catch =       20.420107

Average DCAC            =       20.341328
Median DCAC             =       20.344825

1%    - 99% CI =       20.075870 -       20.582799
5%    - 95% CI =       20.166809 -       20.500234
10%   - 90% CI =       20.211421 -       20.466712
20%   - 80% CI =       20.261185 -       20.423137

Minimum =       19.548216 - Maximum =       20.760917
```

Input Parameters File (.dat): c:\nft\dcac\rossetto.dat

Summary Report File (.out): c:\nft\dcac\rossetto.out

DCAC Output Data File (.aux): c:\nft\dcac\rossetto.aux

When available data do not support population modeling …

Solution for assessment of risk of overexploitation (U.S. National Marine Fisheries Service) in the Bering Sea and Aleutian Islands zone:

CATCH-BIOMASS RATIO

Y/B=F

Risk Criteria	
Catch/Biomass > M	Species may be at risk of overfishing
Catch/Biomass < M	Species less likely to be at risk of overfishing

Are we able to estimate absolute Biomass?

..and catch? Need of a limit RP!

Thanks for your attention