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USE OF SINGLE-SPECIES REPRODUCTION-BASED REFERENCE POINTS FOR THE MEDITERRANEAN DEMERSAL FISHERIES MANAGEMENT

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Introduction

Reference Points are conventional values of the state of a fishery or population that are considered useful for management advice. Biological Reference Points (BRP) used for fisheries management decision makers are derived from mathematical models and generally are expressed in terms of fishing mortality rate (F_{msy}, F_{MBP}, $F_{0.1}$), fishing effort (f_{msy}) or in amount of harvesting (Maximum Sustainable Yield, Maximum Economic Yield, etc). The need of guidelines for the estimation of potential sustainable catches lead policy makers to the choice of a reference point and related operational decisions.

The merits of one reference point over another depends on a number of factors that include population dynamics of the stock and fishing strategy. It is necessary to estimate which is the risk to conduct the stock below some given limit (overharvesting) or to a very conservative threshold characterized to extremely reduced yields (underharvesting) resulting to the choice of one or another reference point.

In this paper many of the main approaches regarding this subject are described and their usefulness and practical application for management purposes in the Mediterranean is discussed .

Reference points based on Surplus Yield Models

The MSY based models useful for the determination of reference points are originally equilibrium models where the points of the curve represent the yield that would result from a given standard effort exercitated for the number of years necessary to reach the equilibrium. The concept of equilibrium refers to the situation produced by a given fishing mortality F_E exerted long enough on a stock to have, its size and rate of net growth, steadily adjusted.(Pauly, 1984).

The classical reference point based on surplus yield models is f_{MSY}. When catch and effort time series are not available rough estimators of the potential yield based on Biomass estimates for unexploited (Gulland, 1971) and for exploited stocks (Cadima, in Troadec, 1977; Garcia et al. 1989) were proposed .

A "rule of thumb" proposed by Alverson & Pereyra (1969) that F should equal M at the level of Maximum Sustainable Yield is considered by Francis (1974) totally lacking of theoretical basis from the standpoint of the Schaefer logistic production model.

Recent papers shows that in some circumstances this rule can drastically over or underestimate the ratio between F_{msy} and M depending on the relative importance of growth in pristine production and to the degree of density-dependence in the stock-recruitment relationship (Thompson,1992). Deriso (1982) showed that the fishing mortality rate obtained with his delay-difference model at MSY was consistently greater than the natural mortality rate when recruitment is constant while the situation is reversed under other stock/recruitment assumptions.

Caddy and Csirke (1983) presented data proceeding of 11 stocks where F_{msy} is from a third to five times the value of M. They also concluded that this rate doesn't show any functional relationship with the species lifespan.

According to Beddington & Cooke (1983) there are three major problems related with the use of the Gulland approximation:

1) The MSY as a proportion of the unexploited biomass, depending on the choice of the age at recruitment, should be less than $1/2*M*B_o$.
2) Harvesting at this MSY mostly involve a reduction of the spawning stock biomass leading to a recruitment reduction.
3) The high variability of recruitment even when parent stock is unchanged.

Csirke & Caddy (1983) proposed another reference point (F_{MBP}) that should replace f_{MSY} or F_{MSY} as benchmarks for management advise. The F_{MBP} was defined as the fishing mortality rate that leads to the Maximum Biological Production of the stock. The MBP level is reached when the total production of the stock (that includes fishing as well as predation mortality) is maximized. This occurs at a level of effort below that providing MSY.

Reference points based on Dynamic Pool Models

Classical dynamic pool models (Beverton & Holt,1957; Thompson & Bell,1934; Ricker,1975) describe the changes of the biomass of a fish cohort after recruitment. The number of individuals of a year class decreases as a result of fishing activity and natural losses. The biomass of a year class is obtained by multiplying the number of survivals by their mean individual weight. Initially, an unexploited year class increases its biomass because the high growth rate dominates the losses in number due to natural mortality until it reaches a maximum at the so-called "critical age" t*. After this point its biomass declines (the natural mortality predominates on the moderate growth rate). When fishing begins too early or the fishing mortality rate is too high, the fish in average is caught before the year class achieve its critical age and part of the potential yield is lost.

For a yield-per-recruit-based analysis, the optimal harvest strategy should be to catch all the fish at the "critical age" at which the cohort reaches its maximum biomass. This could be obtained with an ad hoc fishing strategy that allows the escapement of all the younger fish and with unlimited effort over the individuals of this critical age. If the species reaches the sexual maturity after this age, this strategy is obviously not sustainable. Reed (1980) suggested that if the stock/recruitment relationship does not involve overcompensation, the optimal exploitation policy of a resource does not necessarily involve the problem of harvesting before the critical age. For the Arcto-Norwegian cod, harvest is concentrated on 6 years old individuals while the age of first maturity is 7. Reed determined as the optimal harvesting policy the catch of the 44% of the age 6 individuals with no other harvests, saving the old, slow-growing individuals for reproduction.

The F_{max} estimate is very useful relative to short term yield but ignores the likely effects of fishing on the self renewal of the stock. Deriso (1987) discussed the inadequacy of F_{max} as a desired management level. The Yield per recruit curve is very often nearly flat in the neighborhood of the maximum. As a result, for moving from an F that corresponds to 99% of the yield available at F_{max} to that of the F_{max} it would be necessary a disproportionate increase in fishing effort with a negligible improvement on yields. If a relationship between recruitment and fishable stock abundance exists, unless a strong density dependence mechanism is present in the recruitment process, F_{max} will be higher than the F that produces the Maximum Sustainable Yield.

The Gulland & Boerema (1971) reference point $F_{0.1}$ (marginal yield criterion) corresponds to the point on the Y/R function with the slope of 10% of the slope through the origin. Behind this reference point there are considerations that includes the effect of fishing on the future recruitment. The advantage of this approach is that it does not reduce spawning biomass so severely and that it takes in account economic aspects. The $F_{0.1}$ concept intrinsically incorporates the effects of the growth rate, the age of recruitment and natural mortality. In consequence, F_{msy} will be less than M for slow growing stocks or stocks with low age of recruitment and will exceed M for fast growing or stocks characterized by a high age of recruitment. Even if it has no real biological basis, most of the Canadian resources were managed for a long time under the $F_{0.1}$ concept.

Clark (1991) concludes that $F_{0.1}$ is probably a reasonable exploitation rate when recruitment and maturity schedules coincide. If in the majority of the cases fish have a chance to spawn before recruitment to the fishery, the optimal F is much higher than $F_{0.1}$. When maturity is delayed and fish sustain some fishing mortality before spawning, $F_{0.1}$ tends to overestimate the optimal fishing mortality rate.

Based on the simple yield per recruit theory of Beverton & Holt (1957), Deriso (op.cit) states that there is a unique size of first capture that maximizes yield per recruit when an $F_{0.1}$ management strategy is applied . The "optimal $F_{0.1}$ criteria" should be, according to Deriso, the unique size of entry into the fishable population that maximizes yield under a $F_{0.1}$ regime. He showed that optimal $F_{0.1}$ criteria can be characterized by the single quantity M/K (natural mortality rate/Von Bertalanffy's growth constant). His theory was tested for three different fish stocks assuming a Ricker (1954) stock/recruitment relationship.

"Total allowable catch" ("TAC") is a level of catch corresponding to a chosen level of fishing mortality (generally determined with the $F_{0.1}$ criteria). This reference point has been widely utilized for stock management purposes in the North Sea and North Atlantic. It is "the maximum total catch that can be allowed to be taken from a stock by everyone fishing it in any one year to meet a specified management objective" (Pope, 1982). It varies from year to year and, when the stocks are shared by more nations, administrators have to negotiate each time divisions in quotas.

Estimates of TAC's contain uncertainties due to assessment problems but the most important sources of variation are the inherent variability of fish stocks and any change in management strategy aimed at increasing long-term yields (e.g. changes in exploitation pattern). The causes of the failure of this management policy, even utilizing conservative catch quotas, may be related with the needs of accurate real time estimates of catch, age composition and standardized fishing effort for the TAC's estimates (FAO, 1993). This is only possible if sampling design, gross catch reporting, utilized population models and parameter estimates are appropriate.

For a randomly fluctuating environment, when overexploitation reduces the population biomass to a level smaller than the MSY, Beddington & Cooke (1983) re-examined the basic Beverton & Holt model and provided two tables with maximum sustainable yields expressed as a portion of the unexploited recruited biomass and to the total unexploited biomass for different ages of recruitment, natural mortality and values of the Von Bertalanffy growth constant K.

Beddington & May (1977) suggest that high effort produces a low average yield with a high variance. These effects are expected to be more pronounced for a constant catch quotas harvesting strategy than for one based on constant effort.

Recruitment overfishing and Biological Reference Points

The recruitment overfishing can be defined as the level of fishing pressure that practically depletes the spawning biomass producing a drastic reduction of recruitment or its complete failure.

The spawning biomass of a year class over time (the sum of the biomasses for all ages older than the age at first maturity times the fraction mature at age) is affected by the fishing strategy. Traditional yield-per-recruit analysis do not consider any reproductive constraint and assume constant recruitment and its independency of stock size.

The main problem to solve aimed to a rational management policy is to choose a measurable fishing mortality rate that provides a good compromise between approximating F_{msy} and avoiding stock collapse for a range of plausible S/R relationships and other life history characteristics (Mace, 1994)

The potential yield of a fishery should be determined by a complex interaction between fishing effort, gear selectivity, life history parameters of the exploited species (growth, natural mortality rates, fecundity) and the underlying spawner/recruit relationship.

Many methods were proposed recently for combining dynamic pool and spawning stock/recruitment models but these methods are of reduced utility without a well defined S/R relationship. Data provide little support for the construction of reliable models like Ricker (1954), Beverton & Holt,(1957), Shepherd, 1982), that describe the relationship between generations. The main causes for the poor fit of S/R models could be the use of biologically too simple models and the "noise" caused by abiotic factors that obscure the biotic relationships (Walters & Ludwig, 1981).

Some simple "rules of thumb" were proposed as warning signals of recruitment overfishing. The simpler one is that the mean age at first capture should be older than age at first maturity.

Caddy & Die (in press) modified the Beverton & Holt (1956) equation incorporating the inequality $L_{mean}>L_m$ in order to give an upper limit for Z that in average allows a fish to mature before be caught. This reference point can be useful to monitor a fishery as it develops.

Sissenwine & Shepherd (1988) define recruitment overfishing in terms of "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". At this level the population should fluctuate without trend. Sissenwine & Shepherd proposed the use of conventional models and usual sets of data to determine the level of F denoted as F_{rep} related to the replacement of spawning biomass and as a consequence to sustainability of a population and yields in the long term. The proposed reference point ignores compensatory processes. If compensation exists, F_{rep} is a conservative reference point and it is supposed that the population can exploit its compensatory reserve in order to sustain a high fishing mortality rate. If there is depensation, the F_{rep} is not conservative and the population may collapse even if fishing mortality is at or below the F_{rep} level. In this case, they propose to give, during computations, a compensatory heavier weight to the most recent values of S/R.

Norris (1991) stated that the Sissenwine & Shepherd method is "safe" because allows to determine a sustainable level of fishing effort that maintain recruitment at an equilibrium level. In some cases, however, generates F values corresponding to yields that are so far from the optimal. Assuming an asymptotic spawner/recruit relationship and a overfished stock characterized by a reduced level of biomass in equilibrium, the F_{rep} allows the stock self-replacement but the level of F so obtained is not economicaly adequate because $F_{rep}>>>F_{MSY}$. Norris concludes that the results obtained with this approach are highly dependent on the range of stock sizes of which spawner/recruit data are available.

With the aim to determine adequate yield levels, Clark (1991) made simulations with a range of typical values of natural history parameters and Spawner Biomass/Recruitment relationships for demersal fish. He stated that appropriate yield values should be at least 75% of the MSY if the spawning biomass is maintained in the range of 20-60% of the virgin level, independently of the form of the model assumed for the spawning biomass/recruitment relationship. A fishing mortality rate that reduces the spawning biomass per recruit to about 35% of the virgin level, maximizes the minimum yield among all of the spawning biomass/recruitment relationships considered. Clark defined this value of F as F_{mmy} (maximin yield rate). Its real value depends on the time relationships between growth, age at first maturity and fisheries recruitment. It appears to be very close to Gulland and Boerema's $F_{0.1}$ except when ages at maturity and recruitment do not coincide. In this case F_{mmy} should be considerably bigger or smaller than $F_{0.1}$. Between the two methods proposed by Clark aimed to obtain high yield with little risk, namely: harvesting the surplus production of the resource obtained keeping the spawning biomass at 20-60% of the unfished level and fishing consistently at $F=F_{mmy}$, only one is preferable in any particular circumstance. The former, if implemented by a smoothing process aimed to stabilize annual catches, is preferable when the stock abundance in equilibrium appears constant producing narrow confidence intervals for the spawning stock biomass estimates. However, the equilibrium abundance varies considerably even for lightly exploited or virgin stocks. For stocks characterized by a highly variable biomass, fishing at the F_{mmy} level may be as a consequence the best strategy. Clark states that in this way, it is possible to account for natural changes in equilibrium abundance and obtain yields very close to MSY under any fishing regime. However, the F_{mmy} strategy is less robust than the former because it is more sensitive to the form of the S/R relationship and to errors of estimates of M.

Myers et al.(1994) studied the problem of estimating a minimum biomass reference level at which recruitment is severely reduced. They investigated several methods for estimating spawning stock biomass thresholds utilizing data for 72 finfish populations, each one with at least 20 years of data. The conclusion is that the stock size corresponding to the "50% of the maximum predicted average recruitment" is generally preferable because "easily understandable" and relatively robust even if only data of low stock sizes are available. It nearly always results in threshold levels in which the mean recruitment is much higher above the threshold. Methods like the 20%B_o are not recommended because they generally place the critical point beyond the range of the observations. There are two problems related to the utilization of such methods: the accuracy in the estimates of virgin biomass that assumes stationarity and the universal application of the 20% level approach since different stocks are characterized by different degrees of compensation in recruitment or in any other biological process.

Quinn et al. (1990) constructed a simulation model of an age-structured population with stochastic recruitment aimed to assess the consequences of harvesting strategies by means the utilization of several threshold levels. The model was tested giving different factors as fishing mortality, recruitment and initial biomass. It was concluded that the most important factors in determining the optimal threshold levels are the reproductive potential and the spawning biomass/recruitment relationship. The reproductive potential should be negatively associated with the threshold level. The threshold levels, if the resource follows a Ricker S/R model, should be higher than those corresponding to a Beverton & Holt model.

Mace (1994) states that the validity of $F_{0.1}$, F_{max}, $F_{20\%}$ or other reference fishing mortality rates as approximation of F_{max} or as thresholds of recruitment overfishing strongly depends on species life history characteristics and particularly on the importance of density-dependence fenomena in the Stock/recruitment relationship. The "extinction parameter" þ is defined as the ratio between the slope corresponding to the Spawning Stock per Recruit at F=0 (or 1/$SPR_{F=0}$) and the slope at the origin of the S/R model (1/δ for the Beverton & Holt model). High values for þ mean extremely low compensation capacity at low stock sizes (for þ=0.5 is only about twice that at the virgin size). Values of 0.05 mean high compensation survival at low biomass (about 20 times the virgin rate). A default value of þ=0.2 (survival at least five times the virgin rate) is commonly assumed in the United States in overfishing definitions for management purposes. In the choice of a reference point as the F_{msy} or the $F_þ$ (extinction threshold of fishing mortality rate), several population parameters are involved. The F_{msy} decreases with increasing þ and increases with K (Von Bertalanffy growth constant) and M (instantaneous natural mortality rate).

According with Mace (op.cit) F_{msy} has the highest sensitivity to þ, next to M and last to K. For low values of þ, (0.05-0.1) $F_þ$ is usually high sometimes exceeding $F=3*F_{msy}$. Reference points derived from Yield per recruit analysis ($F_{0.1}$, F_{max}) as well as from Spawning per Recruit analysis ($F_{20\%}$, $F_{35\%}$) are not influenced by þ but increase with both M and K. Mace & Sissenwine (1993) calculated median survival ratios for 83 sets of S/R observations and obtained an overall average value of þ=0.19. Estimates for highly resilient species as Gadus morhua were in the range 0.05-0.15. Mace and Sissenwine recommend the utilization of a 0.2 value for stocks believed to have at least average resilience. In case of little known stocks with insufficient S/R observations the 80th percentile result (þ=0.30) should be adequate.

The sustainability of F=M to set an upper bound on þ is justified by the fact that most fish show for long periods sustained biomasses at this exploitation rate. F=M according to Mace et al. is generally a conservative estimate of F_{msy} but for some parameter combinations (low M and K, high þ) simulations suggest that may be less conservative than is commonly assumed.

Mace states that Reference Points derived from Spawning Stock per Recruit analysis are likely to be superior to those derived from Yield per Recruit analysis because they incorporate reproductive constraints. The Biomass per Recruit estimates derived from SS/R considers the likely effects of age of recruitment substantially disparate to the age of first maturity t_m. In fact, when differences between t_c and t_m do exist, $F_{35\%}$ and $F_{0.1}$ values diverge. When there are insufficient observations to characterize the S/R function over its entire range, Mace suggests that the Sissenwine & Shepherd F_{rep} approach can be used as the basis for an F "Limit Reference Point" or as a "Target Reference Point" if the observations proceeds from a fishing activity that operates "at near-optimal levels".

Sissenwine et ali (1988) provide a review of population models and biological reference points used for management advice when the form of the S/R relationship is uncertain. They also provide results based on stochastic harvesting models and show how difficult is to manage fluctuating resources even if the form of the underlying population processes is well undertood. This is mainly due to the relative variability in yield and population siza that generally increases with increased exploitation rate and environmental variability. A constant catch strategy will drive to low mean yields and even to a stock collapse if sucessive several years of poor recruitment occurs.

Recruitment variability is a source of uncertainty in population size estimates specially for overfished populations. Possible errors in population size estimates automatically lead to errors in catch quotas. Sissenwine et al. (op.cit.) states that this problem is more probable if there is non-stationarity and autocorrelation in the recruitment series. Stochastic harvesting models are able to provide more realistic management advice and allow to evaluate the risks associated with any management strategy.

During the last years, the number of papers regarding the application of risk analysis and decision analysis is considerably increased (Walters et al., 1988; Overholtz et ali.,1991; Francis, 1991; Restrepo et al.,1992); Hilborn et ali., 1994).

Egg-per-recruit and stock replenishment models

Percentages of stock which would be replaced due to reproduction or egg-per-recruit estimates can be calculated with dynamic pool models for different ages at first capture and fishing mortality rates (Caddy,1977; Campbell,1985; Breen,1986, Sluczanowsky,1987; Smith at al.1990). In the simpler way, it is done by summing over ages from age at first maturity (t_m) to maximum age (t_{rho}) the products of the female survivors per recruit and the number of recruited juveniles or eggs produced by females at each age and multiplying the sum by 100 or expressing it as a percent of recruits that should be produced by the virgin stock. For the computations are necessary estimates of fecundity as a function of age, fishing mortality rates, and in some cases estimates of larval-juvenile natural mortality rates. Incorporating egg per recruit relationships into a Y/R model and solving for the age-specific fishing strategy that maximizes yield, Getz (1979) and Reed (1980) proved that the optimal harvesting policy assume different forms depending on which age classes are caught by each fishing strategy. This kind of approach, however, do not take in consideration neither density-dependent compensatory mechanisms on growth and mortality rates nor any S/R model .

As shown in fig.1 for Nephrops norvegicus in the Central Mediterranean, (from Abella & Righini, not published) percent of stock replacement per recruit increases steadily as F tends toward 0 or tc increases. It is possible to select a safe level of fishing rate that allows the self renewal of the stock. In this case, the present age of first capture (tc=3) with a fishing mortality rate of 0.4 can be considered as a safe combination regarding an F Limit Reference Point of 1.6 (the fishing mortality rate that produces an 100% of stock replacement for a given fishing pattern). At low fishing mortality rates, it is shown that replacement is nearly independent of age at first capture. For age at first capture above 3 combined with any value of F>0.6 replacement is nearly independent of fishing mortality rate. The shape is not unexpected but is probably unrealistic in the case of very low mortality rates or very high tc where some density-related compensation mechanism should exist in order to eliminate the probability of a species demographic explosion. It is possible for higher exploitation rates or too young age of first capture that density-related compensation mechanisms of inverse sign should also occur. In this case, the natural mortality rates utilized, specially the estimates of M for the younger individuals, have to be considered overestimates of the true values. The consequence of these possible events should be a more conservative estimate of the optimal F and tc combination for the stock. Fig.2 shows different reference points obtained for a Mediterranean Nephrops population by means different alternative methods.

Biological Reference Points adopted for management advice

The International Council for the Exploitation of the Seas ad hoc working group initiated in 1984 a discussion with the goal to find alternative target exploitation levels to $F_{0.1}$ and F_{max}.

Yield per Recruit results have been generally plotted as Yield or Biomass per Recruit as a function of F while Parent Stock/Recruitment information expressed in the form of Recruitment as a function of Spawning Biomass. The slope of the line joining the origin to the mean of stock sizes and recruitments of different years represents the average recruitment per standing stock and it is the reciprocal of Biomass per Recruit. It is in this way that these two relationships may be linked. Slopes representing good and poor recruitment, corresponding approximately to the ninth and first deciles, can be defined and related to an F level (F_{low}, F_{high}) and to the Biomass per Recruit graph.

During the last years, also the United States fisheries management is based on appropriate biological reference points paricularly as regard spawning stock biomass/recruitment analysis. Safe values (Limit Reference Points) for SSB/R are considered those bigger than 20-35% of the virgin stock level (Anon.1991, Thompson,1993). These values, however, seem to vary considerably depending on taxonomic groups. For the eastern Bering Sea/Gulf of Alaska (Caddy, 1993), a set of constraints was developed for stocks management namely: Reduction of the stock up to 20% of its virgin biomass; a maximum F that corresponds to nearly 30% of the relative %SSB/R; a maximum F that should be up to 80% of the M value.

The necessity of the availability of enough individuals to replace the spawning biomass of their parents was adopted as a management goal of the Multispecies Fisheries Management Plan for New England (NEFMC, 1985). This approach is based in Sissenwine & Shepherd (1987) proposal.

The "minimum biologically acceptable level" was recently adopted by the International Council for the Exploration of the Sea with the aim to prevent recruitment overfishing.

The North Pacific and Pacific Fishery Management Councils adopted the management term of "Acceptable Biological Catch" that should provide both conservation and optimal utilization of the resources. This approach is justified on the basis of relevant biological and ecological information. This strategy consists in the multiplication of the best estimate of exploitable biomass by an exploitation rate that should be no higher than M when other informations are lacking. The catch must be zero if the stock is at or below its threshold estimated by means the analysis of relevant scientific information. If information is lacking, the threshold will be fixed arbitrarily equal to 25% of the average biomass of the virgin stock.

The International Whaling Commission adopted a level of biomass for the so-called "protected stocks" that corresponds to 0.54% of its virgin biomass.

The choice of a Mediterranean strategy

The Mediterranean demersal stocks are generally fully exploited or overexploited. However, often is not possible to fulfil the necessary stock assessment requests. The application of conventional stock assessment models in order to give management advice is not always possible. The main cause is the lacking of many ancilary informations regarding species natural history and fishery. For many countries neither commercial nor research vessel surveys reliable information regarding data series of catch rates, population structure, etc. is available. The multispecific-multigear characteristics of the fisheries, the extremely dispersed landing sites and the fact that many times only a small portion of the catch passes through organized fish markets make catch assessment surveys in the area particularly difficult and expensive. Due to the traditional practices of fish manipulation and selling, species separation is incomplete and this fact make difficult the direct estimation of total landings by species. Total catch is difficult to estimate because discards at sea are a common practice. There are limited opportunities for taking size composition of the catch due to the high prize of the species and to the customary practices of stratification of fish by commercial value independently to taxonomic criteria. In this context it is necessary a large number of samples with the aim to obtain representative length compositions.

Several approaches have been applied in many Mediterranean countries for stock assessment purposes. Yield per recruit analysis has been one of the most frequent utilized method probably due to its relative simplicity and reduced data requirements. However, the results are often not convincing. These failures can be attributed mainly to the choice of the model in relation to a given fishing strategy or to the inadequacy of the input values utilized.

Surplus models have been also frequently utilized but many times the results are not reliable. Among the main causes of the frequent failures regarding the application of this kind of approaches there is the choice of a nonrepresentative unity of fishing effort and the difficulties regarding its partitioning, the lacking of historical data series and the imprecise estimations of total catches specially in the case of stocks which are shared by more than one fishery or country. However, this kind of models, in principle, show clear advantages because they allow to an easy examination of any change in equilibrium yield due to variation in fishing effort and describe the interactive effects of recruitment, growth and natural mortality in a single compensatory function such as the logistic model (Sissenwine et al., 1988).

The use of surplus production models using Z as a direct index of fishing effort and Z_{MBP} or F_{MBP} as reference points should avoid the main problems refered above and should constitute one of the possible approaches to develop in the near future for the assessment of the Mediterranean resources. Z_{MBP} and F_{MBP} estimates obtained assuming a Shaefer model correspond to lower exploitation rates than F_{MSY} and this difference progressively increases for species which position is low in the food chain and that are characterized by higher natural mortality rates. Caddy (in FAO,1993) states that the results obtained by applying this proposal is the reduction of risks of ecological perturbation when the stock is at its maximum productive capacity, making the use of F_{MBP} more conservative than F_{MSY}.

For many multigear fisheries in the Mediterranean, the lack of good time series of catch and effort and the difficulties related with effort partitioning and fishing power standardization have discouraged scientists from attempting stock assessments based on the likely relationship between catch and effort. As a tentative to avoid these problems it was made a proposal (FAO,1985; Abella,1986) that consists in fitting a composite surplus production model utilizing overall instantaneous mortality rates Z as a direct index of fishing mortality (Csirke & Caddy, 1983). It was proposed to obtain annual estimates of Z and catch rates from trawl-surveys data assuming that for all the surveys, the same fishing strategy was utilized. If the amount of the total annual catch is unknown, with this approach we will not be able to estimate the F_{MSY} but the Z_{MBP}. In some cases, specially when the informations regarding a stock are scarce, this should be advantageous because the level of effort that corresponds to the Z_{MBP} is in general more conservative than the f_{MSY}.

For the utilization of traditional surplus production models, time series of Z estimates and biomass indexes are needed. It is also necessary that noticeable changes in fishing effort have occurred during the analyzed period. In order to solve these problems it was proposed the utilization of the "composite model" (Munro,1980) consisting in a replacement of the CPUE and f time series by couples of these data proceeding from different areas with similar ecological characteristics and exploited with different rates (Fig.3). Data can proceed from a very restricted period of time. A similar basic productivity before the departure of the fishing activity and similar evolution under fishing pressure is assumed for all the areas included in the analysis. This combination of Csirke et al. and Munro approaches has been tested by Abella (not published data) for Norway lobster and pink shrimp in the Sicily Strait and by Ardizzone & Cau, (1990) for hake in the Central Tyrrhenian Sea. In both cases the results seems very consistent. This method can be applyied for non migratory species that are vulnerable to the bottom trawl net.

Dynamic pool models are considered the faster approaches in order to provide stock assessment advice. This is mainly due to the relatively short time necessary to data collection and to calculate the parameters that constitutes the input of the more simple models. Caddy (1993) states that the main difficulties related to yield calculations for the Mediterranean resources is related to the values assigned to the more important population parameters (assumed constant values for natural mortality rates independent of age, simple growth functions that do not describe adequately the early growth in weight, etc.). Overholtz et al, (1991) examined the impact of compensatory changes in growth rates, sexual maturity and natural mortality rates on the Northwest Atlantic mackerel stock and their consequences on catch and spawning stock biomass as well as the consequences on any one of these factors of changes in the exploitation pattern and fishing strategy.

Many times, errors on the sampling statistical design, the low sampling intensity, the unknown catchability coefficients as well as availability of resources regarding the fishing instrument produce imprecise and/or inaccurate estimates of biomass and of the population demographic composition. For stock assessment purposes of multispecies-multigear fisheries like most of the Mediterranean that are characterized by complicate fishing patterns, the choice of a suitable model is particularly critical. For many stocks, the different age classes are exploited with different rates, age at first capture is too low and often a unique value of M for all the recruited age classes is assumed even if it is known that M is very high during the early life stages and declines with age. The widely utilizad Beverton & Holt model is not suitable for such situations. The Thompson & Bell yield forecast model seems more efficient in these cases due to its elasticity. However, this model, as well as any other traditional yield-per-recruit-based method, have the common characteristic of ignoring the likely effects of fishing on the self renewal of the stock.

Estimates of total mortality rates and other ancilary data (age at first capture, age at first maturity, fecundity, adult and recruit biomasses, etc.) can be utilized to assess the present fishing strategy but the results have to be compared to some chosen threshold or target reference point that takes in consideration reproductive constraints. From the several proposed reference points, the Sissenwine & Shepherd F_{rep} seems, in the present circumstances, one of the most suitable for the assessment of the Mediterranean demersal stocks. This approach is one of the less data-requiring and its main advantage is that almost always provide sustainable fishing rates. To estimate the F_{rep} reference point is necessary a set of spawner/recruit data. This set can be obtained by means a VPA analysis with length or age composition data of landings or by means of direct methods (trawl-surveys) with the condition that the sampling strategy allows the reconstruction of the real demographic structure at sea. Probably data will be too variable to allow the identification of a proper spawner/recruit relationship but at least, it will be possible to draw a line through the couples of observations that represents the so-called "replacement line", characterized by an equal number of points above and below and to estimate an F_{rep} quite close to the F_{msy}.

The availability of recruitment estimates for a wide range of spawning stock biomass levels should be necessary. This kind of data is often difficult to obtain because almost all the demersal Mediterranean stocks are in conditions of fully exploitation, biomasses are almost in equilibrium and changes in fishing intensity are negligible. In such a situation it is possible to estimate an F_{rep} that is sustainable but this mortality rate correspond to yields that are well above the optimal.

Often, for a single species, estimates of spawning stock biomass and corresponding recruitment proceeding of different neighboring fishing areas are available. These areas could be exploited with different rates. Assuming for all of them a similar initial productivity and a similar evolution of the species structure and size under different fishing pressure levels, it will be possible to evaluate the consequences on recruitment of different spawning biomass levels.

In case of total lacking of stock/recruitment estimates, it will be necessary to chose a simpler approach. Clark (1991) suggested for stocks which the S/R relationship is totaly unknown the choice of the safe fishing mortality rate $F_{35\%}$ that reduces the spawning biomass per recruit to about 35% of its virgin level. Population parameters and maturity-at-age data are required in the analysis.

A limitation of all the approaches discussed in this paper (anaytics or holistics) is that all the reference points so obtained are single-species based and no considerations of interactions with other species are included.

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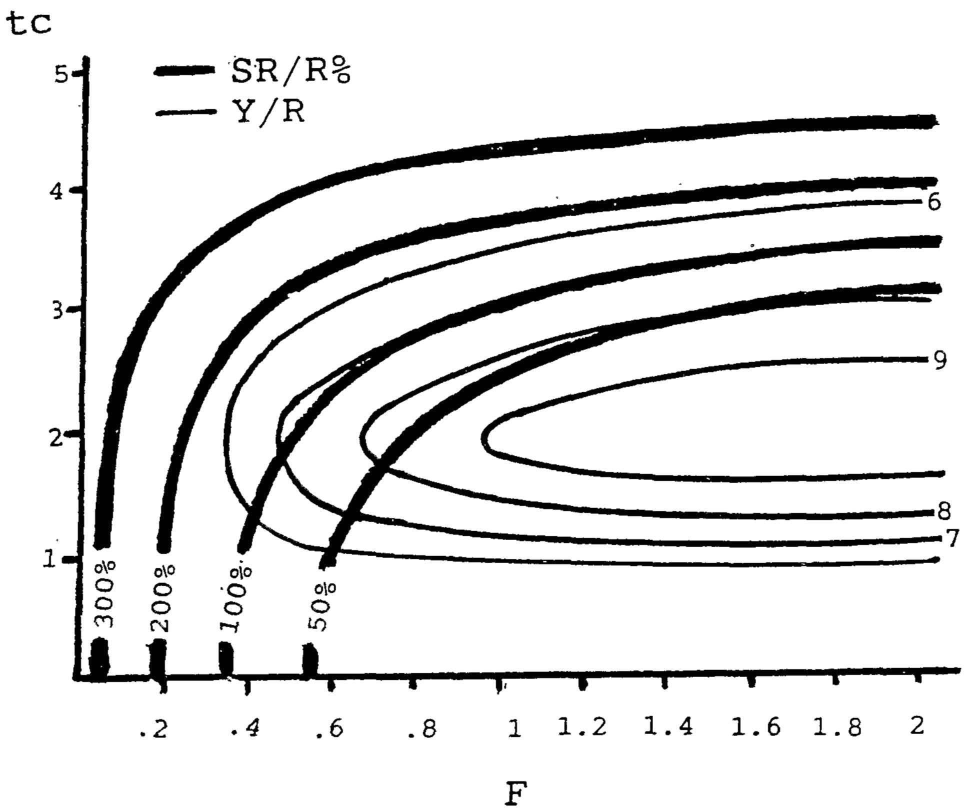

Fig.1 Isopleths of Yield-per-Recruit and Stock Replacement-per-Recruit overlapped for Nephrops norvegicus in the Southern Ligurian Sea.

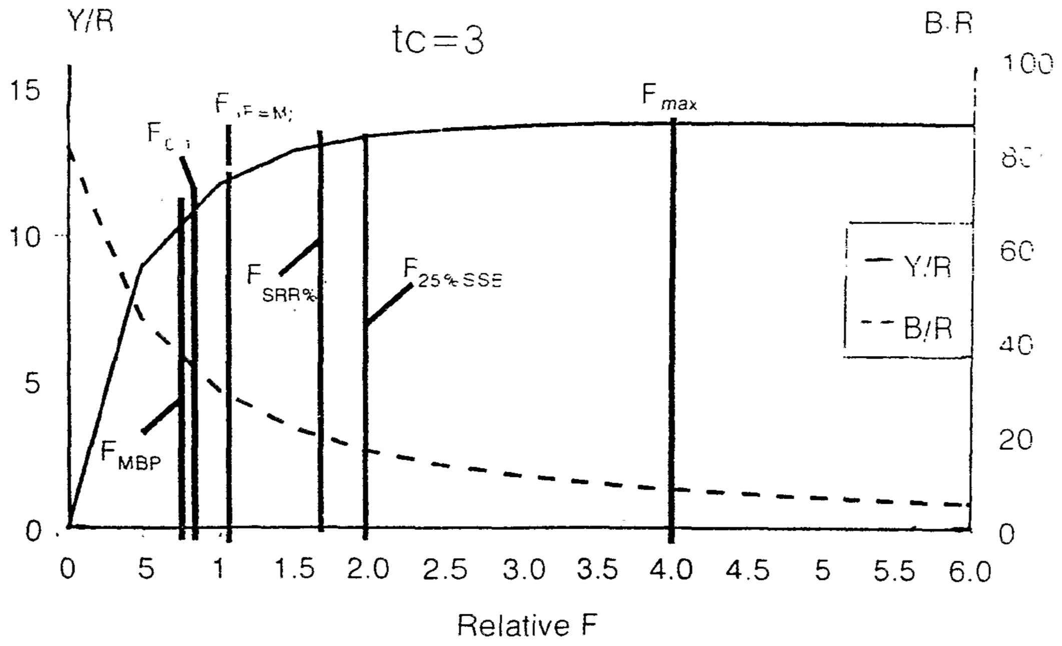

Fig.2 Illustration of different reference points expressed as fishing mortality rates for Nephrops norvegicus in the Southern Ligurian Sea.

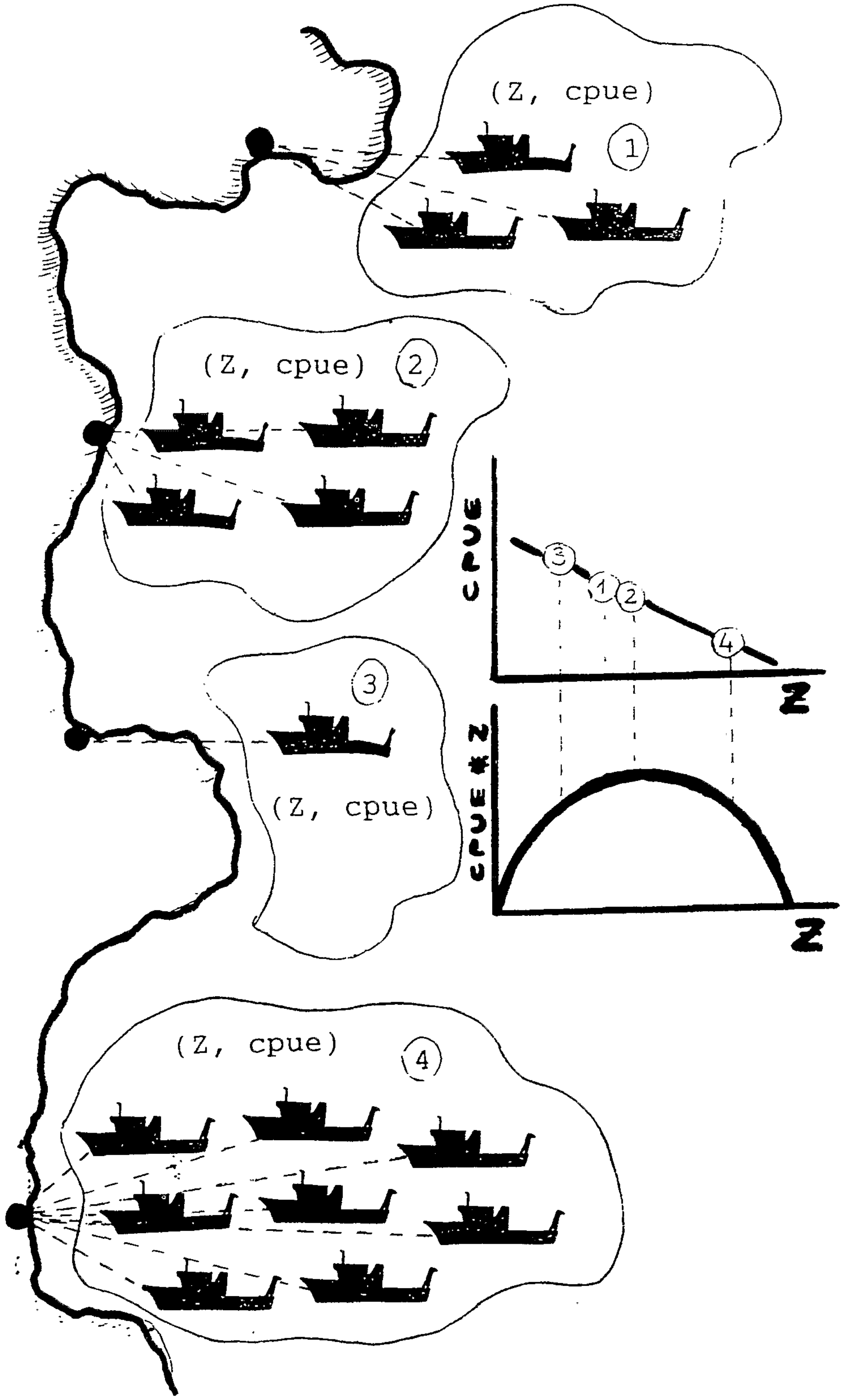

Fig.3 Schematic illustration of data required in order to construct a composite production model utilizing Z as a direct index of fishing effort.