Evaluation and Management of Fishery Resources in the Mediterranean

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The Marine Resources and the Environment

by
Pere Oliver
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Despite a figure of landings of 1.2 millions of metric tons in 1992 (FAO sources), given the current dockside prices, the indicative value for landings of fish, caught by the Mediterranean fleets, is about 3.8 billion dollars annually, making the fishery sector a major contributor to the whole Mediterranean economy. But, although, the stock assessment and the recommendations for management has until now relied almost exclusively on species biology and population dynamics of resources, there is the need to move towards a consideration of the socio-economic aspects linked to fisheries.

In order to introduce an overview of the Mediterranean Fishing System as a whole and to facilitate the empirical use of two models incorporating socio-economic factors of exploitation we will describe the main elements of this System:

Resources ad the Environment
Fishermen, Fleets and Market
Management, Administration and Local Organizations

In relation with the first of these three elements we consider that fishery yields are also conditioned, apart from the fishing activity itself, by factors independent from human control which determine the abundance of the harvested resources: biology of species and environmental factors.

Population Dynamics is a field of scientific research developed earlier this last century in the North Atlantic, to understand the behaviour of exploited marine populations, especially this discipline has become extremely important due its economic and social consequences, when used in support of assessment and management of fisheries. A very important element of Populations Dynamic Analysis and therefore for Stock Assessment, are the biological parameters considered by the mathematical models. In fact the predictions of these models are very sensitive to the estimates of these biological parameters used. We are going to discuss the influence of these parameters on the models and on their biological interpretation.

Although the hydrographic and bioclimatic conditions of an area determine the conditions under which a population can exist, normally they are not considered by the models of population dynamics currently in use. Furthermore, there are two main factors which limit the biomass of the populations: the primary production and the available habitat or space, that are not usually taken in account either. It is imperative to keep them in mind however when interpreting results in order not to come to unrealistic conclusions. Finally the relation between primary production, mainly conditioned by the nutrient input into the euphotic zone, and the total production of fish will be discussed.

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1. The Biological Parameters, their Role in the Models used for Stock Assessment

1.1. Life History Strategies

The useful, if rather over-simplified concept of r-K continuum of life history strategies, first coined by MacArthur and Wilson (1967), has proved valuable in attending to integrate life history information in relation to the role of a species in the marine ecosystem, even if it is difficult to quantify in practical terms. Stated simply, it is postulated that two major evolutionary strategies can be recognized, r and K selection, each of which is particularly adapted to characteristic patterns of change in the biotic or abiotic environment.

In his general review of the field, Pianka (1970) notes that in terrestrial systems there is a very clear distinction between the two strategies, and that in fact, for terrestrial animals this results in a clearly bimodal distribution of sizes, between small (predominantly annual) arthropod-dominated species, and larger, often perennial vertebrates. However, Pianka notes that fish show the full range of the r-K continuum. The r-strategists are species adapted to living in environments where there is a high density-independent mortality rate. Such areas include high latitude seas where (for annual species at least), seasonal periods of high food abundance are followed by periods of relative scarcity. These species tend to allocate a greater proportion of their resources to reproduction, having in consequence a high gonadosomatic ratio and birth rate, a short life span, as well as being in general relatively unspecialized, especially for example in feeding habits. Population size is generally prone to high fluctuations in numbers (e.g., Engraulid and Clupeid species).

By contrast, K strategists are adapted to living in environment, relatively stable, where intra- and interspecific competition is high. There is consequently a high degree of selection by means of density dependent factors, and these species have evolved to allocate a greater proportion of their resources to non-reproductive activities promoting individual survival. They are consequently relatively specialised in their trophic activities and other behaviours, and in general are longer-lived, less fecund, and less prone to major short-term changes in population size (e.g. sharks and whales).

A summary of the main characteristics of r and K selected species is given in Table 1.

Table 1. Some of the characteristics of r- and K-selected species (from Caddy, 1984)

Characteristics	r-selected	K-selected
Climate	Usually variable and/or unpredictable	Fairly constant and/or predictable (or species shows migratory behaviour
Risk of natural death	Often high or catastrophic: largely independent of population size	Death rate is more scheduled and dependent on population size
Population size	Variable in time, non-equilibrium conditions prevail; occupies ecological vacuums but rarely reaches the carrying capacity of the environment;	Fairly constant in time, at or near carrying capacity of environment
Competition between species and within species	Generally lax	Usually keen
Length of life	Short	Longer
Natural selection in favour of:	(1) Rapid development	(1) Slow development
	(2) High rate of population increase	(2) Low rate of population increase
	(3) High rate of egg production	(3) Low rate of egg production
	(4) Small body size	(4) Large body size
	(5) Single reproduction	(5) Multiple reproduction
	(6) Less emphasis on behavioural and morphological charatceristics to increase individual survival habits	(6) Behaviour and morphology assures good individual survival, e.g., territorial behaviour, spines, special dentition and special feeding habits
All above lead to:	Productivity	Efficiency

There are a lot of usefull functions which help to explain the basic concepts of this continuum r-K. These funtions describe asimptotic fenomena like the increase of a population and the use of more space or the consumption of limitated resources like food, approaching an assimptotic value of maximum biomass. We can observe the increase in biomass of a population as proportional to the reproduction rate r, under the assumptions of the logistic model:

$$dB/dt = rB \qquad 1$$

But if the limitant factors are taken in account, the increasing rate of biomass growth can be considered a measure of the speed with which the biomass of a stock of a species reaches the maximal assimptotic value established by these factors. If K express this limit and r is the maximum rate of increase we could use the logistic equation suggested by Verhulst-Pearl, commonly used in demografic studies (Figure 1):

$$dB/dt = rB - (r/K)\,B^2 \qquad [1] \qquad\qquad 2$$

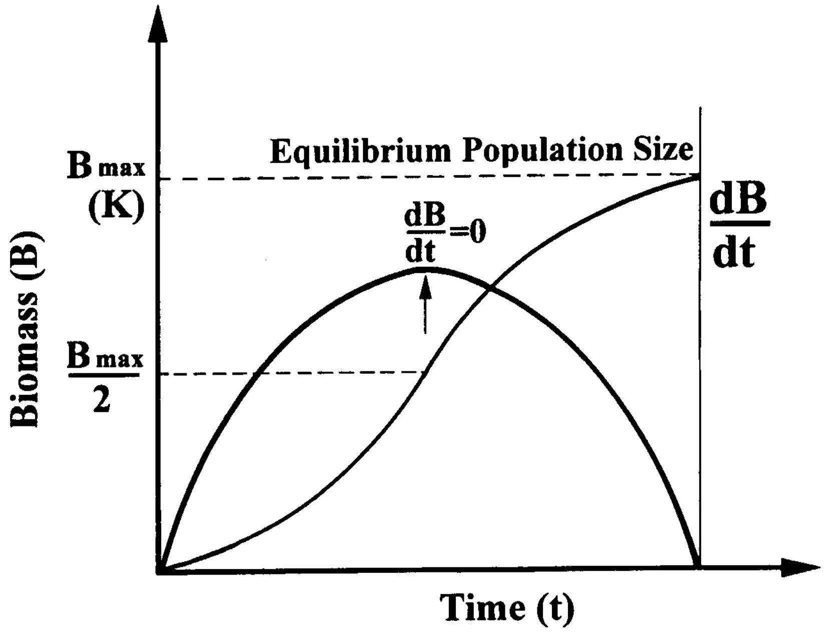

Figure 1. Rate of change of population size and growth of population size with time as described by the logistic model

But if we fish, the population will reduce by some function of fishing rate.

$$dB/dt = [rB - (r/K)\,B^2] - Bqf \qquad\qquad 3$$

and at the equilibrium the fishing catch (C, being q the catchability coefficient) is equal to the generation of Biomass

$$dB/dt = o \qquad C = Bqf \qquad\qquad 4$$

$$C = rB - (r/K)B^2 \qquad\qquad 5$$

or if we consider that the fish catch per unit effort (at equilibrium) Ue is:

$$Ue = C/f \qquad\qquad 6$$

and substitutes in equation 4 we have:

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[1] r is the maximum rate of increase that a population of initial size (B) exhibits when released from exogenous limitations (i.e. not food limited, little predation, etc.), and K the carrying capacity of the system, equivalent to the virgin biomass or the carrying capacity of the environment in the usual fisheries formulation

$$B = Ue/q \qquad 7$$

and substituting in equation **5** and dividing by Ue we have:

$$f = r/q\ (1 - Ue/U_\infty) \qquad 8$$

we can be rearranged to solve Ue:

$$Ue = U_\infty - [U_\infty(r/q)]f \qquad 9$$

where $U_\infty(r/q)$ is the slope (b) of the straight line that allows us to plot Ue against f fitting the past data from the fishery and since:

$$C = fUe \qquad 10$$

by definition, we can get:

$$C = U_\infty f - bf^2 \qquad 11$$

and if we plot this curve on a graf (Figure 2) we obtain a production model in which we can read off the fishing rate or effort (f) needed to achieve different catch levels.

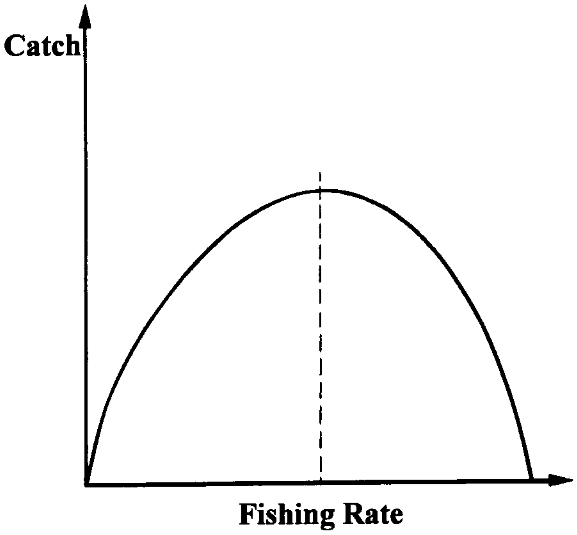

Figure 2

If we return to the r-K continuum, having in mind its role in the previous production model we can realize that it is quite difficult to quantify the utility of these concepts in application to practical ecological problems. However, the interesting relationship between the intrinsic rates of increase, r, and population density could be useful for fishery analysis purposes. For example, if we plot the rate of increase in population against population density as in Figure 3, we see that to the left of some density, X, the r strategist is at a competitive advantage, while to the right, the K-strategist is favoured.

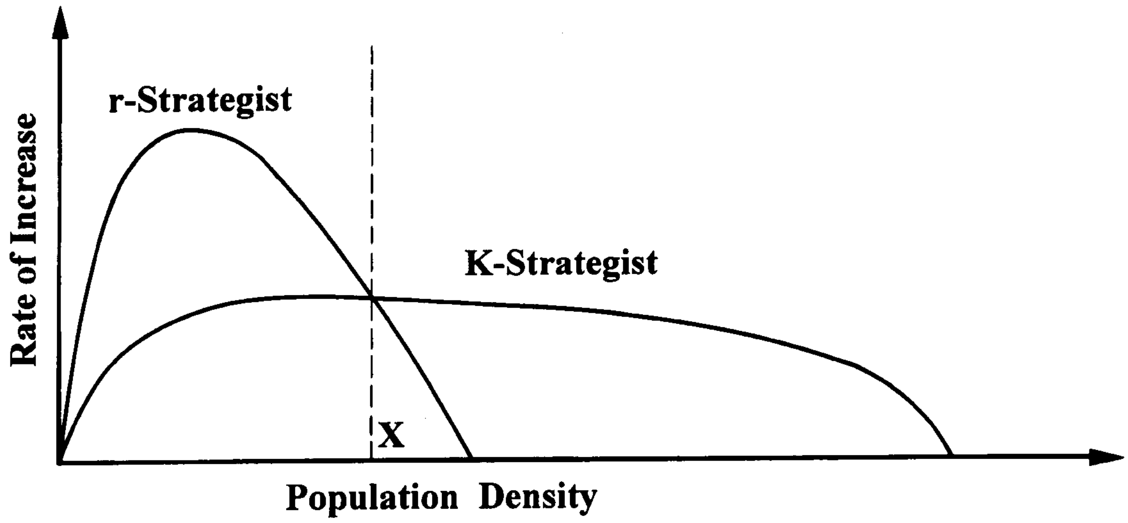

Figure 3. Postulated relationship between population size and rate of population increase for r- and for K-strategists.

1.2. The biological parameters and the lifespan of species of fishes

From a similar point of view the lifespan has been frequently used by fishery biologists to classify species. Attending to this characteristic the species can be grouped as long-lived and short-lived species.

Short-lived species of fishes are characterised by the rare presence in the population of individuals of more than 4 years. Natural mortality (M) is usually high, in the order of $M=1$, with a survival rate of from 35 to 40% in unexploited conditions. The growth rate is high and they reach the sexual maturity in the next year. These species are very influenced by environmental changes. Normally its populations are very variable due to the fact that they are dependant almost exclusively on the most recent recruitments. For that, when these populations are exploited, it is necessary to look for maintaining a minimum acceptable level of spawning stock in order to avoid collapses. On the other hand provided this level is maintained, high levels of fishing mortality can be applied.

Long-lived species of fishes remain in the population 10 or more years. Normally M vary between 0.1 and 0.5 (i.e. a survival rate between 60% and 90% when unexploited). The growth rate is low, and are not fully reproductive until the 3rd year or more. These populations are more stable than the short-lived ones due the fact the large number of age groups reduce the impact of fluctuations of recruitment.

The mentioned characteristics are summarized in Table 2.

Table 2

	Lifespan	**Natural Mortality M**	**Growth** $L_t=L_r\,(1-e^{-k(t-10))}$	**Sexual Maturity**	**Environment dependency**
Short-lived	4 years (exploited fase)	High (± 1) Surv. of 35-40%	Fast K high (0.5) L_∞ low(-50 cm)	1st year	Strong Fluctuant
Long-lived	10 years or more	Baja 0.1-0.5 Superv. no explot. 60-90%	Slow K low (0.1) L_∞high (1 m)	More than 3 years	Little Stable

Somehow, the named "long-lived" species of fishes can be identified with those difined as K-strategist ones and the named "short-lived" species, more opportunistic, with the r-strategist ones. Once we have to insist with the problems of oversimplification, but sometimes could be useful to be aware of this distinction

A relationship between longevity/lifespan Tmax and natural mortality can be established, i.e., the species with a high mortality rate are short lived (see Figure 4). Also a constant M/K relationship is observed in groups of species evolution related; i.e. the speed to the maximum size is bigger when high natural mortality rate exists. Finally a relationship has been shown between Tmax and L_∞ also for a group of species (Figure 4).

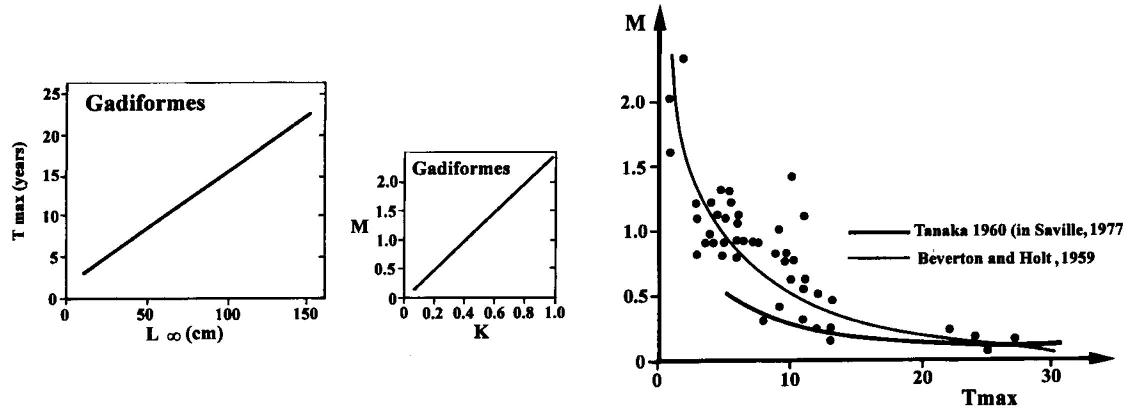

Figure 4

1.3. The Role of Biological Parameters on the Models used in Population Dynamics of exploited Marine Resources

1.3.1. The yield per recruit model

The Population Dynamics, presently, rely on methods that divide the life cycle of species into two phases. The first one, from the spawning, when eggs are expelled into the sea to recruitment, and the second one from recruitment until the new spawning period begins (Figure 5).

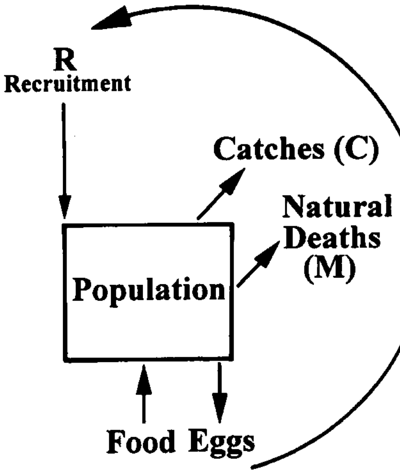

Figure 5.

This second phase is referred as population, stock or resource and when we assume that the population maintain a equilibrium

$$R = M + C$$ [2] 12

But instead of considering numbers we use biomasses, then following the Russell equation (1931) we can consider the growth and the resulting increase in weight, being:

$$B = R + G - M - C$$ [3] 13

The mathematical expressions used in Population Dynamics to model the population behaviour can become very complicated, but are never more than rough views of reality which are much more complex. The most frequently used models (known as "classical models") are the **Analytical Models**. To use these models, besides the characteristics of harvesting being conducted on the population, a knowledge of its biological parameters is needed. Specifically the growth in length and weight, the natural mortality rate, and the relation stock-recruitment or an index of recruitment have to be estimated.

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[2] R is the number of Recruits, M represent the losses in numbers due to Natural Mortality or better due to other causes thatn fishing and C due to fishing

[3] All terms in Biomass units, B is the population Biomass and G the Growth

A simplification of one of the most referred models, the Beverton and Holt Model (1957) or "Yield Equation" can be used to show how these parameters are integrated:

$$Y = F\ Nt\ Wt\ dt \qquad [4] \qquad\qquad 14$$

where the main elements can be estimated through the "Survival Equation" (Figure 6):

$$Nt = R\ e^{-(F+M)\,t} \qquad\qquad 15$$

and the Von Bertalanfy Growth Function (Figure 7):

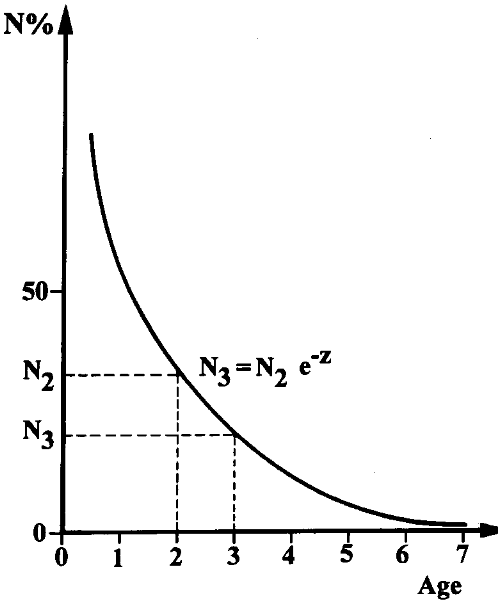

Figure 6

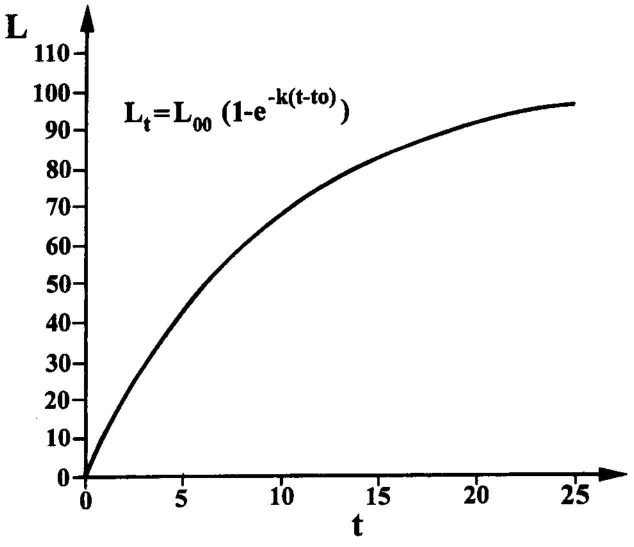

Figure 7

$$Wt = a\ L_\infty 3\ (1 - e^{-k(t-to)}) \qquad [5]$$

Figure 8 shows as how VBGF changes with different values of K (like a speed of growth) and maintaining L_∞ (= 100 cm) and to (= o) constants. When K is 0.1 individuals of 1 year reach 9.5% of L_∞; when is 0.3 are 26%, a 45% when K is 0.6 and 63% when is 1.

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[4] Y is the yield, i.e. catch obtained when a rate of fishing mortality equal to F is used to harvest a resources of N effects of each annual group (t) and being W the average weight of each one of this groups

[5] Von Bertalamfy Growth Function (VBGF) where L_∞ k and t_0 are

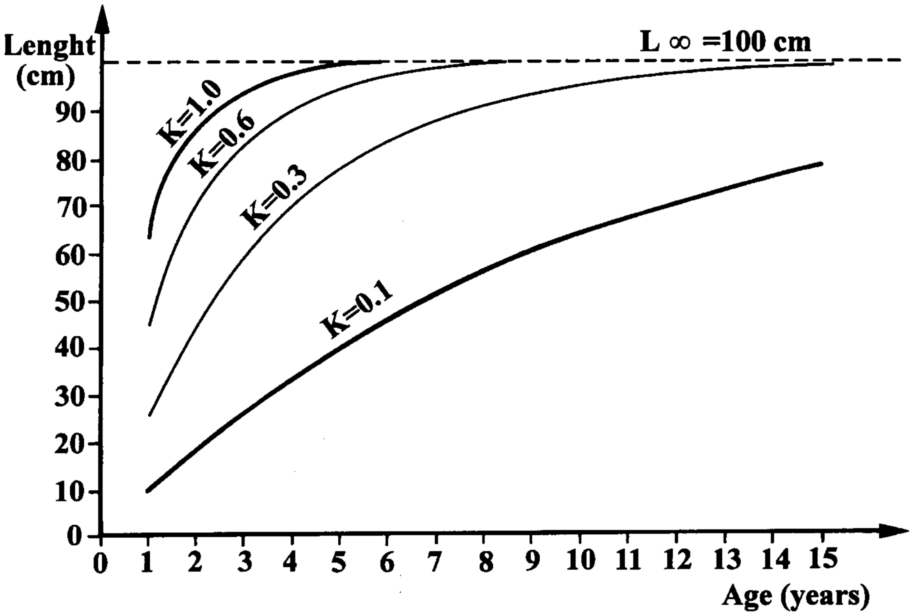

Figure 8.

Furthermore, if we consider the yield per recruit (Y/R) as variable dependent we can construct curves of a population in equilibrium and analyse the variation of Y/R in function of an exploitation parameters like the fishing mortality measured through the fishing effort (Figure 9).

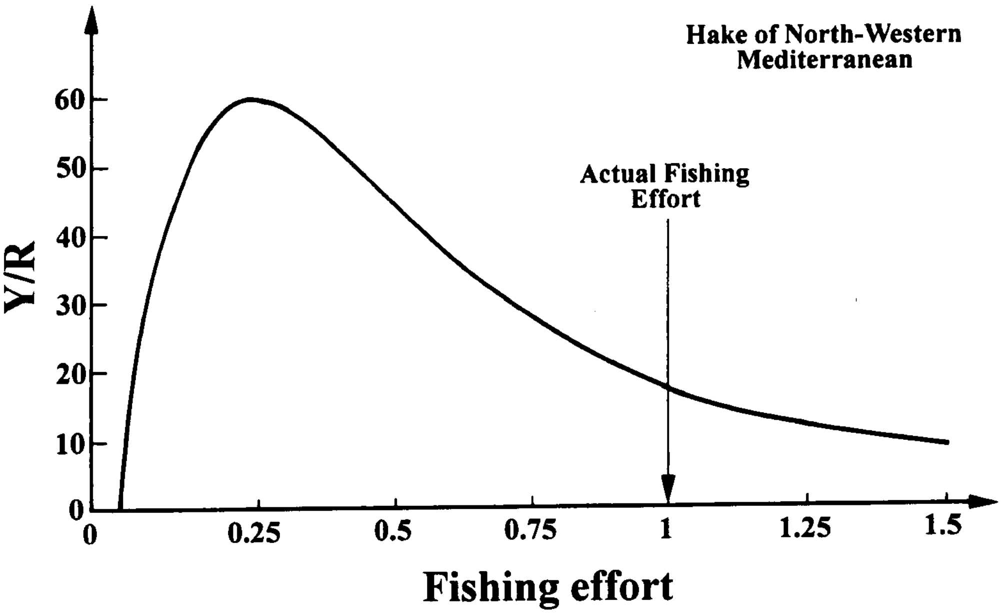

Figure 9

The Y/R curve, logically change depending on the values of the biological parameters used. The Yield per Recruit curves that are shown in Figure 10 (King, 1995), that correspond to a temperate water species, and considering a range of fishing mortalities from 0 to 2.0 (which of course affects the curve shape), allow several generalisations. Figures 10A and 10B indicate how the shape Y/R curve and the Ymax change when growth rate (K) and natural mortality (M) change, unchanging of course the other parameters. The main disadvantages of the model is the assumptions of a steady state. From a practical point of view the model works best when applied to species with low mortality rates, say when natural mortality is less than 0.5. If mortality rates are high the curve may not reach a maximum within a reasonable range of fishing mortality values (Figure 10C). In short-lived species with high mortality rates, the results of yield per recruit analyses may be quite misleading, often suggesting that a extremely high, or sometimes infinite, fishing mortality is required to secure the maximum yield.

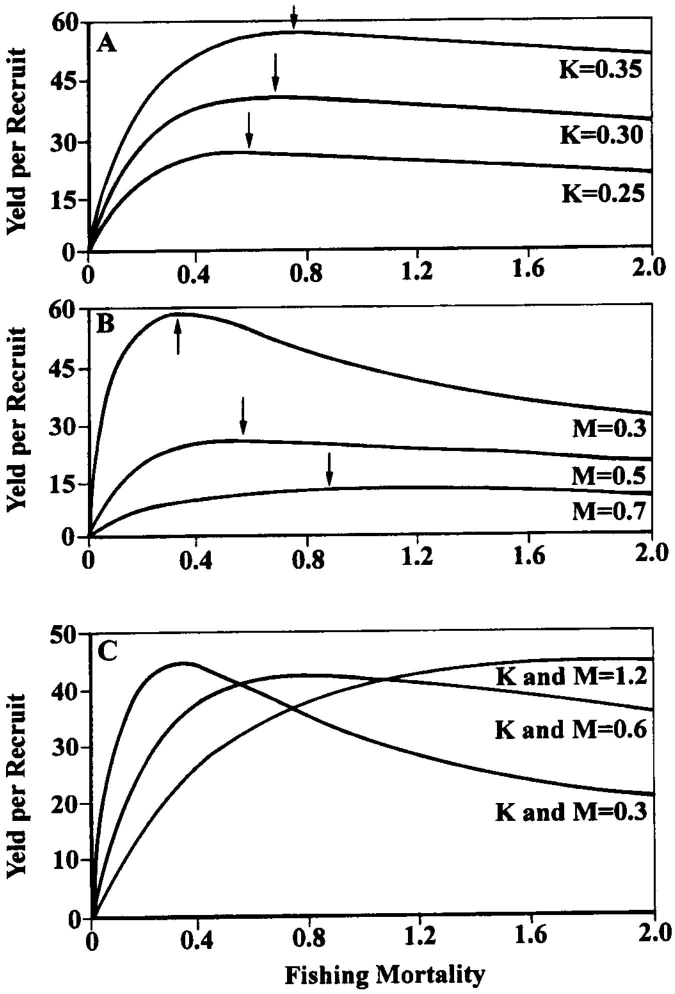

Figure 10

1.3.2. The stock-recruitment relationship

The most common models used to describe stock and recruitment relationships are those of Ricker (1954) and Beverton and Holt (1957), they are two-parameter curves which appear to cover most recruitment relationships. The Ricker's model describes situations with low recruitment at high stock levels and implies strong density dependence, increasing geometrically over a certain range of stock densities. The Beverton and Holt model describes be means aymptotic curves situations of constant recruitment beyond a certain stock density, what implies an arithmetically progressive reduction in the recruitment rate as stock density increases.

The Ricker curves are described by the equation:

$$R = a\,SS^{-b\,SS} \quad [6] \qquad 16$$

The Beverton and Holt's asymptotic curve is:

$$R = 1 / a + (b / SS) \quad [6] \qquad 17$$

In recent years the precautory principle and the sustainability approach applied to mangement of ecosystems and fisheries is receiving much attention. Primary effects of fishing and exploited populations is reduction in stock size and a change in size and age composition towards a lower proportion of larger and older fish, and can be analysed, as we have seen, in terms of fishing mortality, generally through fishing effort. The current understanding of population sustainability can be formulated in terms of minimum levels of spawning stock size, below which the ability of the stock to reproduce itself is reduced or unproven. This minimum level is called MBAL (Minimum Biologically Acceptable Level), less precisely refered as SBL (Safe Biological Limits).

These concepts are based in the fact that when in a population high levels of Spawning Stock Biomass (SSB) exists it is not possible determine the probability of obtaining weak or good recruitments, i.e. it is difficult to establish a clear stock-recruit relationships. Nevertheless at low levels of SSB this relationship it is more clear and the probability of obtain good recruitments decrease when the SSB decrease (Figure 11).

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[6] R are the recruits, SS the spawning stock and a and b the parameters of the curve

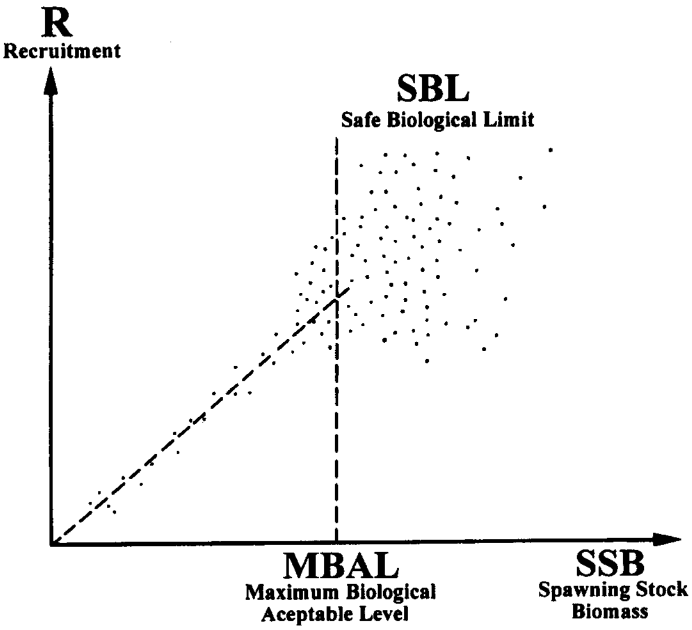

Figure 11

Finally we can note that the plot of rate of increase against density in Figure 3 is functionally equivalent to a stock-recruit model, and further, although this analogy should not be carried too far, than there is a resemblance between the curve for r-strategists and the so-called Ricker Spawner-Recruit (S-R) curve, Figure 12 while that for K-strategists resembles the so-called Beverton and Holt S-R curve (Ricker, 1975). The relationship between the form of the hypothetical spawner-recruit curve and the concept of r and K selection is logical, since both deal with the rate at which a stock replenishes itself under different densities.

Obviously, with no parental stock, there will be no reproduction, but for most species it is still far from obvious what is the relationship between parental stock size and the numbers of progeny produced. In the S-R relationships postulated to date, the number of recruits drops off with biomass or density since as is inevitable in a finite habitat, there is only limited space and food for a certain number of individuals. Line A-B in Figure 12 would only then be approximated in a continually expanding environment.

However we have to indicate that these models analyse the dynamic of populations excluding the interspecific relations as well as the environmental influences, except those influences that can be consider included in M. This fact represents a strong limitation of these models and in some cases can make very unreliable or even invalidate the results obtained.

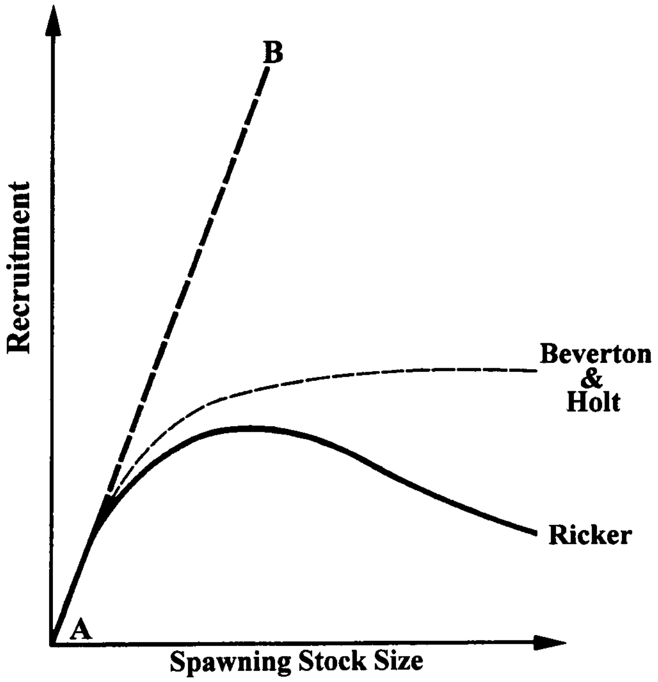

Figure 12. Two relationships between spawning stock size and subsequent recruitment in common use. Line A-B is the trajectory that would apply if recruitment were proportional to stock size.

2. The Role of the Environment

After a collapse produced around 1990 in the Alboran Sea and also in Algeria, its seems that the anchovy landings are actually recovering. But this collapse was not registered in the northern part of Spain and in the Gulf of Lions. A similar process is being observed in the Lligurian Sea where the yields fell before recovering in the last years as has been observed in a similar way in the Adriatic for sardine and anchovy.

But not only small pelagics, in 1991 a coincidence in the increase of the hake landings in different areas of the Mediterranean was observed. A connection or interaction between some key physical factors and biological aspects such as the spatial distribution of eggs and larvae. the state of the larval condition growth (first stages of the life cycle in general) has been suggested to explain these phenomena.

In any case environment obviously affect biomass stock levels. Natural environment changes play a major, and often misunderstood role, and even if natural causes are at the root of the most important changes, pollution also can affect the resources.

Several environmental characteristics of the Mediterranean are relevant for the biology and the behaviour of the marine resources. The general characteristics of the water masses where species live and the general features of the circulation of these waters affect the aquatic systems.

Furthermore, in addition to the hydrografic and bioclimatic conditions of an area there also is an important factor which determine the populations biomass that is the primary production.

The models of population dynamic in use do not take these factors into account, but it is imperative to keep them in mind when interpreting results.

Several situations occur which notably increase productivity. Among these mechamisms of fertilization the existence of permanent or intermittent fonts of divergency, the freshwater outline occasional upwelling associated with wind and eddis from the principal current can be mentioned as the most relevant.

Actually many human activities in the terrestrial components (e.g. industrial, agriculture, depositation, freshwater extraction and human and industrial waste discharge, plus the effects of artificial changes to river hydraulic characteristics), are mediated through river outflows, but the industrial effects of these outflows on the biological components of marine ecosystem can rarely be separated. For that in addition to exploitation, three other anthropogenic impacts on the living marine resources are: reduced freshwater outlow, increased sediment landings and changing nutrients inputs. These impacts should play a large part in understanding changes in coastal marine ecosystems, although whole-system studies of these effects are still rare.

The reduction of the extent of brackish areas and wetlands caused by excessive freshwater extraction upstream will have adverse impacts on marine species which are dependent on brackish habitats for part of their life history. Saltwater invasions of the estuary and lower river system may have other negative consequences on estuarine dependent species and those marine species dependent on reduced salinity conditions for part of their life history, and on anadromous and catadromous species. Increases of saltwater intrusion into estuaries may also favour reproduction and abundance increases of medusae with bottom-dwelling stages, and problems with jellyfish invasions may become more serious through their predators on eggs and larva of fish.

This higher turbidity and reduced light penetration associated with both increased phytoplankton bloomb and/or increased sediment discharge may adversely affect macrophytes such as sea grasses, and macroalgae can be destroyed by particulate laden water from sewage outlets. Loss of vegetated cover can adversely affect recruitment of species such as penaeid shrimp, spiny lobsters and others, dependent on this vegetation for nursery areas and feeding. Areas of gravel and shell bottom valuable for certain species such as oysters may be smothered by siltation through disposal of dredge spoils resulting from the blocking of shipping channels by such siltation; adversely affecting species diversity. On the other hand, some species may be favoured by moderate increases in fines, notably some penaeid shrimp and flatfish species. In general, pelagic production is more resistant to nutrient inputs than that of the demersal/benthic resources, and one may expect that with moderate nutrient loading that pelagic production may increase somewhat.

The environmental impacts, notably from environmental runoff of nutrients into a semi-enclosed sea as the Mediterranean is, have already been documented as having a significant impact on fisheries productivity; an impact that is not entirely negative in moderation, given that Mediterranean food chains were formerly considered seriously limited by availability of nutrients. Since fisheries trends since the 1970's have not been readily explainable in terms of fishing effort alone, which would almost certainly have led to catch declines if environmental productivity had remained constant. Probably, fisheries productivity tracks biological productivity of the system, before eutrophic effects, especially on bottom fauna, leads to declines. Current experience suggests that this decline may be on the verge of occurring for the upper Adriatic, but that southern and eastern Mediterranean environments are still strongly nutrient limited.

2.1. Effects of Nutrient Runoff on Fishery Production in the Mediterranean

Early studies in biological oceanography established the low biological productivity of Mediterranean waters compared with oceanic areas elsewhere, and up to the 1970's fisheries production figures per shelf area were also much lower than the world's average. Evidence has been accumulating for the Mediterranean (Caddy, et al. 1995), and for semi-enclosed seas elsewhere, (Caddy, 1993) that fisheries production in inland seas has been showing a steady rise, even after fish stock assessments have shown that the key stocks are fully exploited. This phenomenon has been tied to runoff of nutrients from catchment basins; and in particular for the Mediterranean, predominantly due to the influence of the rivers Ebro, Rhone, Po, and for the Aegean, to nutrient rich outflow of water from the Marmara Sea. In the case of the Nile, the opposing effect has demonstrated the rule, through a significant decline in sardine landings following construction of the Aswan Dam, and more recently a recovery of production around the Nile Delta and associated lagoons, due to increased inputs of domestic wastes and fertilisers. In the Black Sea, the evidence for the impact of nutrient runoff has been reported, in causing progressive anoxia of shelf bottom waters, especially in the NW Shelf under influence of the Danube and Russian rivers to the north. Episodes of anoxia in the Northern Adriatic have led to localised fish kills, and illustrate that under certain conditions, high oxygen demand due to high nutrient inputs from the River Po, if not diffused, may cause summer kills, suggesting that in this area at least, we may expect further increases in nutrient inputs to lead to declines in production, as has also happened for demersal fish in the Baltic Sea.

Evidently, fishery production is positively influenced, like other biological production, by moderate levels of nutrient inputs, even if these inputs can also lead to negative and noxious effects close to the coast, such as harmful algae blooms, and health and aesthetic impacts, which are of particular concern to tourism and aquaculture, and are likely to damage critical habitats and have effects on biodiversity. It nonetheless emerges from an objective analysis of GFCM fishery statistics that fishery production per shelf area, especially in the Northern Mediterranean which is under the predominant influence of incoming rivers, has been increasing. Evidently there is a risk, especially for the high value demersal fish and invertebrates, that in semi-enclosed basins, estuaries and lagoons, that an excessive level of nutrient runoff will lead to drops in demersal and benthic commercial production, with extremely serious consequences. Judging from experience in the Black Sea, the impact of high nutrient inputs on pelagic fish is not negative, unless eutrophication allows jelly predators such as ctenophores to dominate the pelagic ecosystem, as occurred there, with drastic consequences on the anchovy fishery.

Although it is not possible to separate quantitatively the effects of fishing and of eutrophication on marine fisheries in the Mediterranean, it seems likely that a significant proportion of yield increases since the 1970's, especially in the Northern Mediterranean, are due to nutrient inputs, since evaluations performed since the mid 1970's suggested that we were close to, or at, Maximum sustainable yield, especially for the demersal fish.

The first conclusion therefore from this discussion, is that it would be misleading to consider nutrient runoff as a purely negative phenomenon from the perspective of fisheries, even though this impact is certainly negative for some other sectors. The focus should probably be on placing upper limits to nutrient runoff, and focusing elsewhere in this diagnosis more particularly on severely reducing non-biodegradable and toxic waste discharges, pesticides, organotin residues and other toxic by-products of industry and agriculture.

3. The Mediterranean Resources and their Characterization

3.1. The Target and By-catch Species

Concerning catch composition, and despite the inherent complexity of multi-species landings in Mediterranean ports (see Annex 1), there is an identifiable series of target species which, in biomass or in economic terms, constitute the basis of production. These are sardine (*Sardina pilchardus*) anchovy (*Engraulis encrasicholus*) among the small pelagics; hake *(Merluccius merluccius)*, red mullets *(Mullus* spp.), blue whiting *(Micromesistius poutasou)*, anglerfishes (*Lophius* spp.), *Pagellus* spp., *Octopus* spp., squid (*Loligo* spp.), and red shrimp (*Aristeus antennatus*) among the demersals; and, prominent among the large pelagics, bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*) with other species of local interest in specific sites (FAO 1993). These species represent from 70 to 80% of all landings, at least eight of them over 2% of the total catch, and two over 15%.

Nevertheless in the Mediterranean trawl fisheries sometimes it is not easy to separate target (many times this does not represent more than 20% of landings) to by-catch species because they can change depending of the period of the year, the place and other circumstances. By-catches of trawlers may include small sharks and rays, a group of species that are commercialised together and that can represent, in some cases, up to 40% of total trawl landings. Other species could be cited as by-catches; for example, those caught in small quantities, but important due their economic value; some small pelagic species; several types of shrimps and other crustaceans and cephalopods.

Sardine and anchovy are the main target species of purse seining and mackerels, horse mackerel, bogue, some Sparidae and gilt sardine can be cited as by-catch. The main small scale gears are trammel nets, gillnets, bottom longlines, and the target species are hake, spiny lobster, red mullet, cephalopods, *Poliprion*, Scorpaenidae, Triglidae, *Phicis*, Serranidae, *Trachinus, Trachurus, Scomber, Sarda, Lophius, Boops, Trisopterus* and Sparidae. Traps fish *Plesionika*, spiny lobsters and octopus and dredges catch bivalves as *Donax trunculus, Chameachea gallina, Acantocardia tuberculata, Pecten jacobeus, Callista chione, Venerupis rhomboides* or *Mactra coralina*.

Finally the fleets using floating drifting longline to catch swordfish and tuna long lines and tuna purse seine must be mentioned as surface gears. The main by-catch species of these gears are sharks, marine turtles and also dolphin fish and birds.

In the following figures the target species of main gears in the Mediterranean are included together with the average range of estimated values of biological parameters for each species and by biological categories, as well as informations on landings (weight and value), also by species and by biological categories (in absolute values and in percentage). The observed trend of landing are also included.

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ANNEX

Species or groups of species used by the FAO Fishery Statistics arranged by biological categories resources:

Pelagic resources : *Balistes capriscus, Belone belone,* ***Boops boops****, Brama brama,* Carangidae, *Caranx* spp, Clupeoidei, ***Engraulis encrasicolus****, Lepidopus caudatus, Lichia amia,* Loliginidae-Ommastrophidae, *Loligo* spp, *Pomatomus saltatrix,* ***Sardina pilchardus, Sardinella*** **spp,** ***Scomber*** **spp,** ***Scomber japonicus, Scomber scombrus,*** **Scombridae**, Scombroidei, *Seriola dumerilii, Seriola* spp, *Sphyraena* spp, ***Spicara maena, Spicara*** **spp**, *Sprattus sprattus, Squalus acanthias*, Squalidae, *Todarodes sagittatus,* ***Trachurus mediterraneus, Trachurus*** **spp,** ***Trachurus trachurus.***

Demersal resources: *Argentina* spp, *Argyrosomus regius*, Atherinidae, *Conger conger*, Congridae, *Dentex dentex, Dentex macrophtalmus, Dentex* spp, *Dicologoglosa cuneata,* ***Diplodus sargus, Diplodus*** **spp**, Elasmobranchii, *Eledone* spp, *Epinephelus aeneus, Epinephelus guaza, Epinephelus* spp, *Homarus gammarus, Lepidorhombus whiffiagonis, Maja squinado, Merlangius merlangus,* ***Mullus barbatus, Mullus*** **spp,** ***Mullus surmuletus***, *Mustelus* spp, *Oblada melanura*, **Octopodidae,** ***Octopus vulgaris, Pagellus acarne, Pagellus bogaraveo, Pagellus erythrinus, Pagellus*** **spp,** ***Pagrus pagrus, Palinurus elephas, Palinurus mauritanicus, Palinurus*** **spp**, *Penaeus kerathurus, Platichthys flexus, Plectorhinchus mediterraneus, Pleuronectes platessa*, Pleuronectiformes, *Pollachius pollachius, Polyprion americanus, Psetta maxima maxima,* ***Raja*** **spp, Rajiformes**, Rhinobatidae, *Sarpa salpa, Saurida undosquasmis, Sciaena* spp, Sciaenidae, **Scorpaenidae,** ***Scyliorhinus*** **spp,** ***Sepia officinalis***, Sepiidae-sepiolidae, Serranidae, ***Solea vulgaris***, Sparidae, *Sparus* (= *pagrus*) spp, *Sparus aurata, Spondylosoma cantharus, Squatina squatina*, Squatinidae, Synodontidae, ***Trachinus draco***, *Trigla lyra*, Triglidae, *Trisopterus luscus,* ***Trisopterus minutus***, *Zeus faber.*

Slope resources: ***Aristeus antennatus***, *Cancer pagurus, Corallium rubrum*, Gadiformes, **Lophiidae,** ***Lophius piscatorius, Merluccius merluccius, Micromesistius potassou, Nephrops norvegicus***, *Parapenaeus longirostris, Phycis blennoides, Plesiopenaeus edwardsianus, Squilla mantis.*

Littoral resources: Bivalvia, *Carcinus aestuarii, Cardium edule, Crangon crangon, Crassostrea angulata, Dicentrarchus labrax, Dicentrarchus* spp, *Donax* spp, Gastropoda, Gobiidae, *Gobius* spp, *Littorina littorea, Microcosmus sulcatus, Mollusca, Murex* spp, *Mytilus galloprovincialis, Ostrea edulis, Palaemon serratus, Paracentrotus lividus, Pecten jacobaeus, Reptantia, Ruditapes decussatus, Siganus* spp, *Solen* spp, Spongidae, *Tapes pullastra, Tapes* spp., *Umbrina cirrosa, Venus gallina.*

Estuarine resources: *Alosa* spp, *Anguilla anguilla, Lithognathus mormyrus, Mugil cephalus*, Mugilidae.

Highly Migratory Resources: *Auxis thazard-A. rochei, Coryphaena hippurus, Euthynnus alletteratus Katsuwonus pelamis, Lamna nasus, Orcynopsis unicolor, Sarda sarda*, Scombroidei, *Thunnus alalunga,* ***Thunnus thynnus, Xiphias gladius.***

ANNEX

Modelling the Effects of Nutrient Runoff

As noted, an exact quantification of nutrient impacts is not possible, but it may be concluded from existing fisheries statistics which show a plateau of landings, that current levels of nutrification have reached or recently exceeded optimal levels in the Adriatic and Gulf of Lions. We are probably approaching these optima also for the Aegean and directly off shore from the Nile Delta. Judging from satellite imagery of ocean colour, other areas such as the Levant and much of the southern Mediterranean, can still be considered strongly nutrient limited, and may show further increases in fishery yield if coastal runoff of domestic and agricultural nutrients continue. Over the long term, given the long period (quoted as of the order of 80 years), of nutrient accumulation and recycling of land runoff is likely to complete the conversion of the northern Mediterranean from an oligotrophic system to a eutrophic one some time in the 21st century. The implications of this obviously go beyond issues related to fishery production, and are not dealt with further here.

At the end of these text a simple mathematical model attempts to illustrate how increases in fishery production can occur when fishing intensity has exceeded levels that would result in catch declines under stable levels of biological production.

$$Y = [cP - gP^2]f - bf^2 \qquad 18$$

This model may in future be tuned to fit the observed situation and hence tied to relative impacts of fishing and nutrient enrichment, but for the moment this is intended purely for purposes of illustrating synergistic effort of fishing effort and increases biological productivity due to increased nutrient runoff from land (Figure 13)

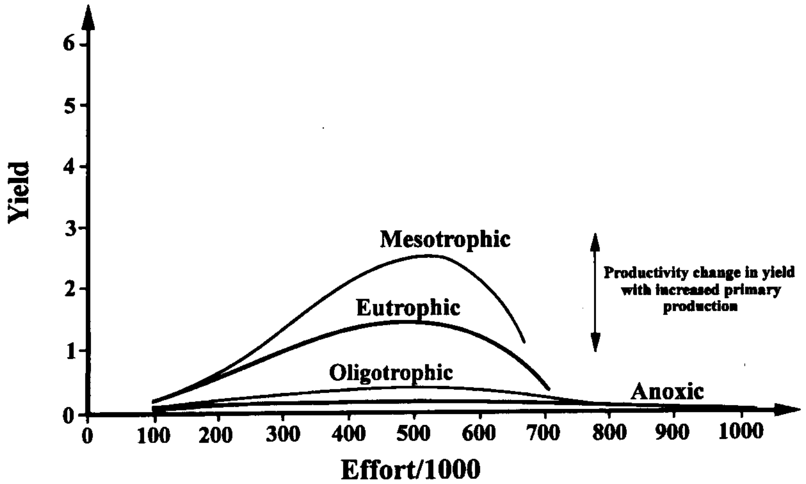

Figure 13. Hypothetical interaction between effort and primary production as it affects fishery yield.

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[7] Y is the yield, P the primary production and f the fishing effort

DEMERSAL SPECIES[1/]

283 392 mt[4/]
US$1 678 758 000

24% weight[4/]
38% value

$K<0.3$
$L_\infty >30$ cm
$M< 0.35$

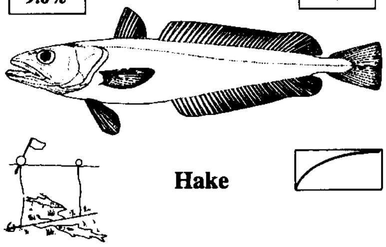
Target species of trawlers and other selective gears

Shelf species

Slope species

3.4%[3/]
9.6%

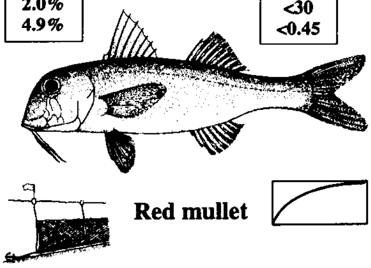
<0.2[2/]
(<100)
<0.4



Hake

2.0%
4.9%

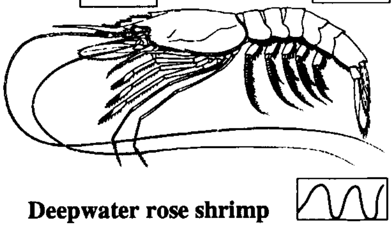
<0.20
<30
<0.45



Red mullet

1%
9.2%

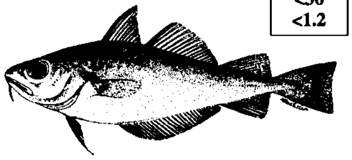
<0.3
<76
<0.5



Deepwater rose shrimp

Bycatch of trawlers

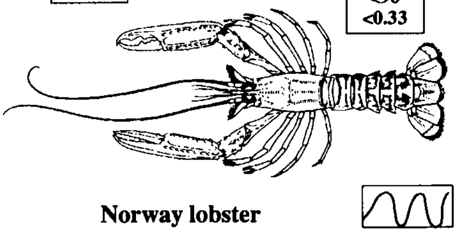
<0.6
<30
<1.2



Poor cod

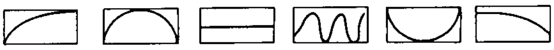
0.4%
3.4%

<0.09
<90
<0.33



Norway lobster

Trend of landings (FAO Statistics)



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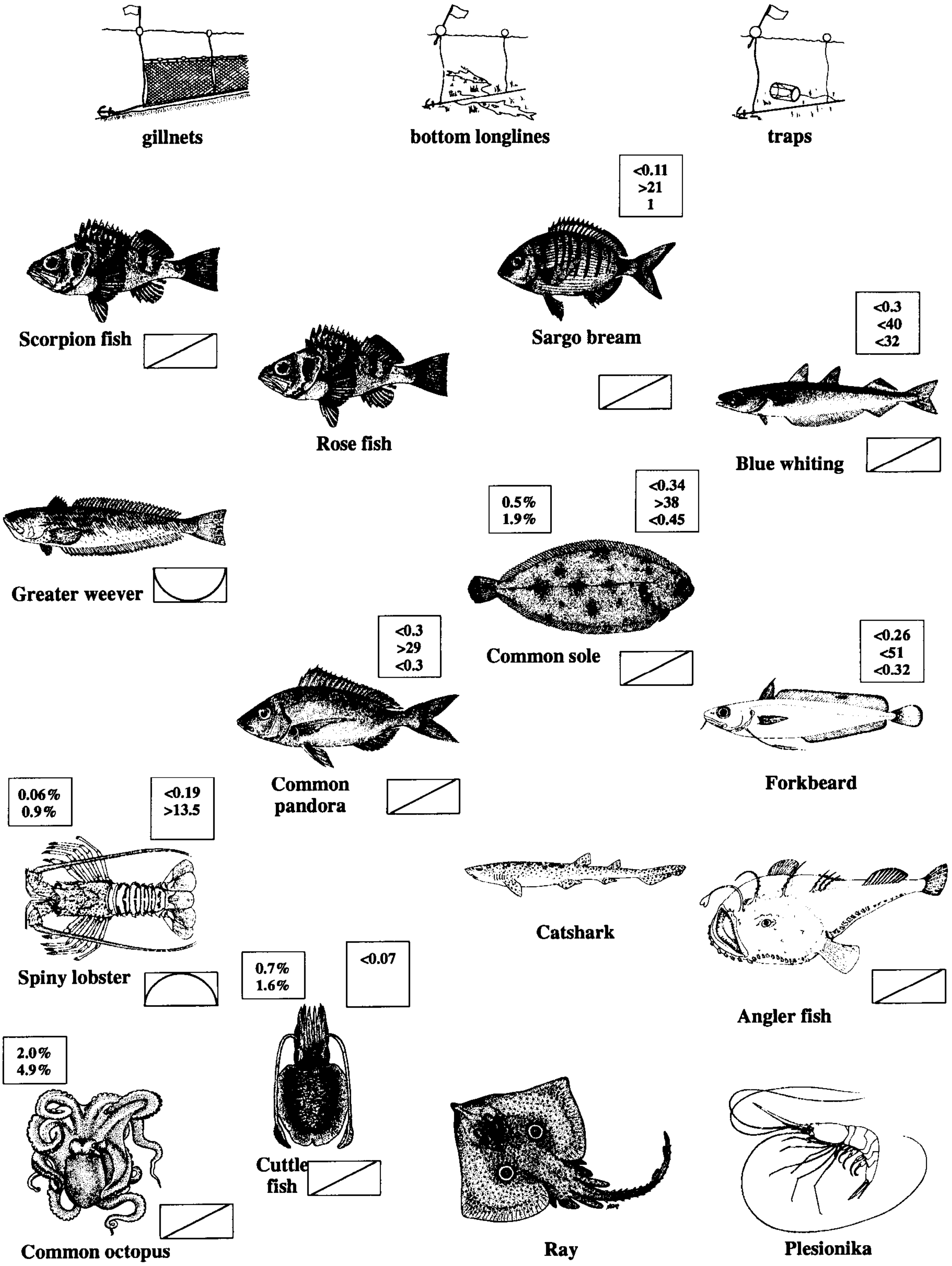
1 Marine Species (31 000 MT/US$ 95 million) bivalves, small decapoda (234 000 MT/1220) and coral and sponges not included
2 FAO Popdyn database
3 in Spain (1991)
4 FAO Statistics

Bycatch of trawlers and target species of selective gears



SMALL PELAGIC SPECIES

493 604 mt
US$549 824 000

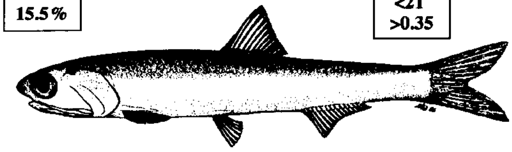
42% % weight
12.4% value

K>0.3
L_∞ <40 cm
M>0.2

Target species of purse seiners

16.1%
15.5%

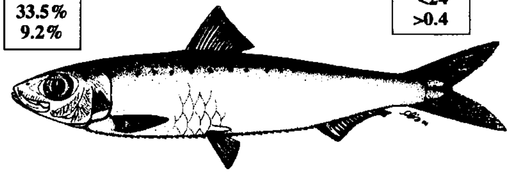
>0.3
<21
>0.35



Anchovy

33.5%
9.2%

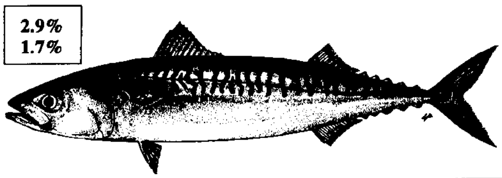
>0.26
<24
>0.4



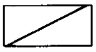
European pilchard

Bycatch of purse seiners

2.9%
1.7%

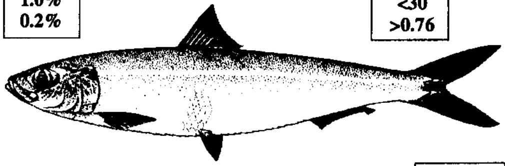


Atlantic mackerel

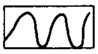


1.0%
0.2%

>0.37
<30
>0.76

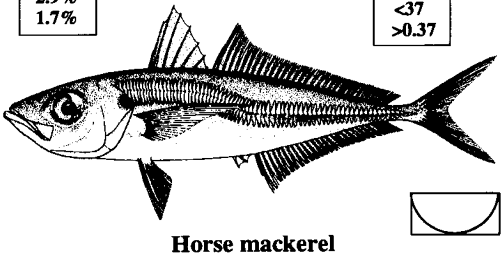


Round sardinella



2.9%
1.7%

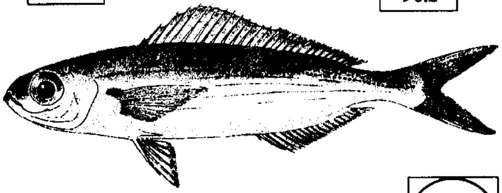
>0.2
<37
>0.37



Horse mackerel

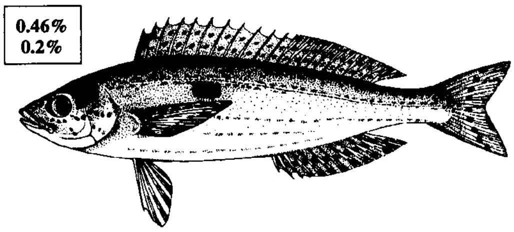
6.1%
0.02%

>0.11
<41
>0.2



Bogue

0.46%
0.2%



Picarel

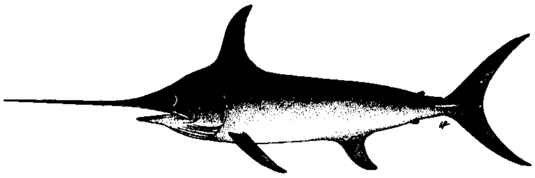
HIGHLY MIGRATORY PELAGIC SPECIES

56 468 mt
US$248 604 000

4.8% weight
5.6% value

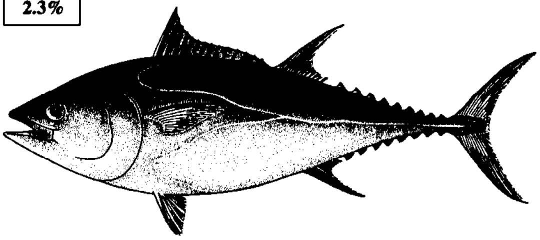
Target species of longlines

0.3%
0.008%



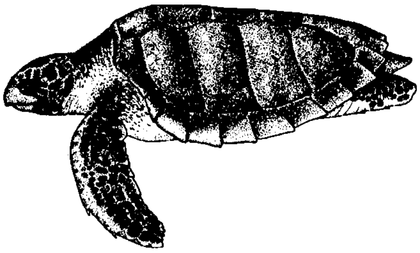
Swordfish

1.9%
2.3%

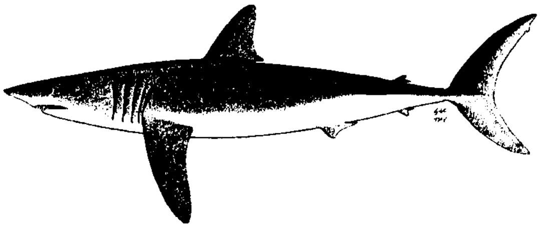


Bluefin tuna

Incidental catches



Loggerhead turtle



Shortfin mako