Small pelagic stock assessment (1984 – 1996)

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Abstract

Data on anchovy and pilchard stock assessment in the Adriatic Sea (between 1984 – 1996) were reported. Different methodologies (echosurvey, eggs and larvae survey, population dynamics) were utilised in order to estimate biomass. Small pelagic fishery resources fluctuated markedly during these years (anchovy stock in particular), but the different assessment methodologies provided comparable results. Information on the distribution and consistency of clupeiform fish shoals in Italian seas was also reported.

1. Introduction

The nekton, as is widely known, numbers just a few species, however the biomass of small nektonic teleosts fishes represents the principal resource for fisheries and for human consumption. We are dealing here with small pelagic fish linked to zooplankton resources on which they feed by means of the gill rakes with which they are equipped.
Small pelagics are for the most part made up of clupeiforms and account for the highest percentage of national fishery landings, about 100000 t a year. This is about 30% of all captured fish and 20% of total fishery landing (IREPA, 1995). The most common and widespread clupeiforms in the Mediterranean are the European pilchard, also commonly known as the sardine, (*Sardina pilchardus* Walb.) and the European anchovy (*Engraulis encrasicolus* L.), also present are species such as the sprat (*Sprattus sprattus* L.) and the gilt sardine (*Sardinella aurita* Valenciennes).
The sardine is found all over the Mediterranean, except along the Libyan coast. It reproduces in zones characterised by isotherms between 10° and 20°C, the larval stages are present from October to May in coastal areas. The size at first maturity, 15 cm, is reached in the second year of life; the life span is between 5 and 6 years with a maximum length of 20 – 25 cm and a weight of over 50 g; mortality for adult classes is estimated at 60 – 80%. Fecundity in the Southern Adriatic is 351 egg/g. The species is a partial spawner with a frequency of up to 15 spawnings. (Sinović 1986, 1991; Casavola *et al*., 1996_a; Anonymous, 1998; Marano *et al*., 1998_a).
The anchovy is found all over the Mediterranean and the Black seas, a gregarious species, it approaches the coast in spring when the temperature rises. It reproduces from April to October, the eggs and larvae are concentrated in coastal waters. Sexual maturity is reached at

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the end of the first year at a length of 11-12 cm; the biological cycle in the Mediterranean is about three years long during which it reaches a maximum length of 20 cm. Fecundity in the Southern Adriatic is 437 egg/g with as many as 20 spawnings. Towards the end of the autumn the anchovies move away from the coast and descend to greater depths. Natural mortality is estimated at between 60% and 100%. (Piccinetti, 1970; Palomera and Lleonart, 1989; Sinović, 1991; Casavola *et al*., 1996_b; Cingolani *et al*., 1998).

Other clupeiform species captured are the sprat in the Northern and Central Adriatic and the gilt sardine in the Southern Adriatic and Southern Thyrrenian Seas. These two species only occur along the Italian coasts because they are sensitive to variations in the main environmental parameters (temperature and salinity). The distribution of sprattus, a northern species, is limited by the relatively higher temperature and salinity of the Southern Adriatic waters, while the species *Sardinella aurita* restrains its diffusion towards the north of the basin due to the lower values of these same environmental parameters.

Small pelagic fishing activity is chiefly concentrated in the Adriatic, a eutrophic basin, using purse seiners during the reproductive season of the anchovy (April – October) or using pelagic trawlers all year round. During the months of February and March juvenile fishery, locally called "bianchetto" fishery, of *S. pilchardus* is carried out, in particular in the Gulf of Manfredonia; on average bianchetto fishery amounts to 500 t. (Ungaro *et al*., 1994; Marano *et al*., 1998_b).

The abundant presence of small pelagics in the Adriatic is linked to the high concentration of nutrients in this basin caused by the run off from rivers, which amounts to over 6000 m/s. The enrichment of the waters determines the development of phyto- and zooplankton (copepods and cladocerans) which allow the small pelagic stocks to feed and reproduce (*e.g.* the trophic chains *Nitschia-Penilia-Engraulis* and *Coscinodiscus-Calanus-Sardina*), (Pèrez, 1976).

In recent years anchovy biomass showed an increasing trend, reaching considerably higher levels than those observed in the 1980s when negative fluctuations were apparent and production was minimal throughout the Adriatic. The studies concerning evaluation of the biomass available for clupeiform fishery (sardine and anchovy being the most abundant species), together with the landing data, have shown that as the biomass of one species increases, a decrease in the other species can be observed. The two stocks show this alternating pattern in relation to trophic and spatial competition, even if recent studies indicate a reduction of this phenomenon. Indeed it can often be noted that both species experience a contemporary increase in biomass, as occurred from 1993 – 1996.

Small pelagic biomass fluctuation seems to be linked to the relatively high mortality rate of juveniles, larvae and ichthyoplankton (Piccinetti *et al*., 1982).

Resource contraction or collapse are phenomena which have not been observed exclusively in the Adriatic, but also occurred in the same years in the sea off the Balearic Islands, an area known to be rich in small pelagic stocks. The phenomenon observed in the Black Sea can also be considered typical, here the *Clupeonella* stock decreased by as much as 400 times in relation to the extraordinary increase in the population of the ctenophora *Mnemiopsis leidyi* A. Agassiz, active predator of fish eggs and larvae (Zaiksev, 1993).

2. Results and discussion

It has been the task of fisheries research to study fluctuations in biomass of clupeiforms in areas where there is a substantial concentration of small pelagics. Estimates of this fluctuation have been made by numerous research groups using several techniques and methods. Research carried out using population dynamics methods (Ancona Research Groups, coordinated by Cingolani), demonstrated noticeable fluctuation in biomass assessed for *E. encrasicolus* in the Central and Northern Adriatic over the years (Figure 1).

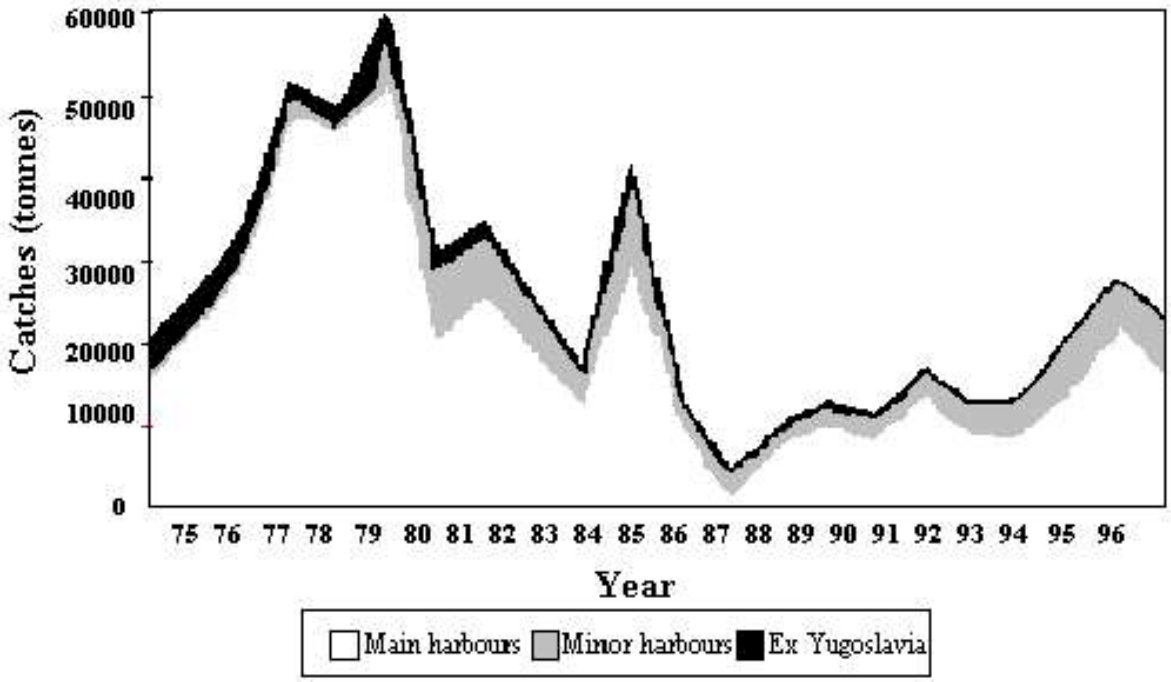

Figure 1. Anchovy: catches in the main Italian ports, in the minor ones and in the ex Yugoslavia (from Cingolani *et al*., 1998).

The greatest abundance was noticed in 1978 when it peaked at 350000 t of estimated biomass, lowest levels were reached in the crisis of 1987-1988, as research using various techniques showed. This was followed by constant increase in the 1990s with biomass estimated at 135000 t/y (Figure 3). Between 1993 and 1996 the highest biomass levels were observed of all the time series of research from the 1987 crisis onwards.

Stock projections (DeLury method) demonstrated that biomass levels are very sensitive to recruitment as this represents a relatively high fraction of the whole population and also because the species has a short lifespan (Figure 2).

In contrast, an increase or decrease of 30% in the fishing mortality rate (F) has a moderate effect on the size of stocks which can be predicted for the following years. The catch level in the last few years is about 20 – 25% of estimated biomass and thus would appear to have only a marginal effect on stock size (Figure 3).

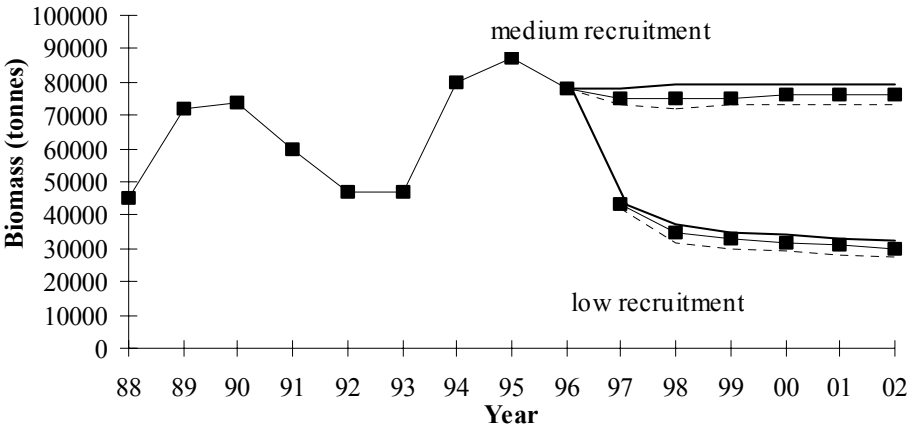

Figure 2. Anchovy: mid year biomass projections by CEDA software, using different fishing mortality rates (F) and levels of recruitment.

During the years in which the study was carried out, *S. pilchardus* showed a peak in estimated biomass in the period 1981 – 1982 (Figure 4).
Following this period, estimated biomass remained relatively stable despite some variations; minimum value was registered in 1993 with a clear recovery in recent years (Figure 6). Landed catch was 10 – 15% of the estimated biomass, therefore fishing effort would not appear to influence fluctuations in the biomass of the population, these changes are principally linked to environmental and climatic factors.

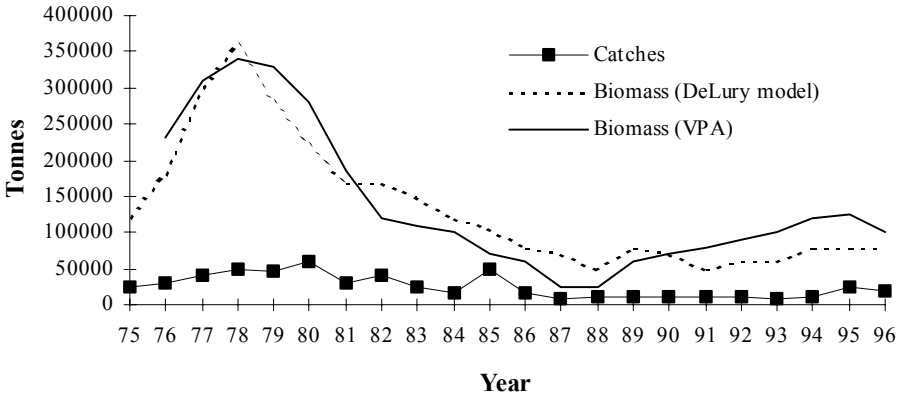

Figure 3. Anchovy: catches and mid year biomass estimated by VPA and DeLury model (from Cingolani *et al.*, 1998).

The size of exploitable sardine stock is also directly linked to the success of, or increase in, recruitment rather than the variations in fishing mortality rate (Figure 5 and Figure 6).

As far as the sardine population in the Adriatic is concerned, research has been carried out regarding the study of the stock's genetic composition, in order to determine whether or not there is more than one population present.
The results of this research confirmed the presence of just one population in the entire basin (Anonymous, 1998).
The research carried out using acoustic methods to assess the biomass of anchovy and sardine populations in the Adriatic also showed fluctuations over the years, especially where the anchovy is concerned, (Ancona Research Groups, coordinated by Azzali).
The estimated biomass of the two most common clupeiforms in the Adriatic for the last ten years is somewhere between 500000 – 780000 t.

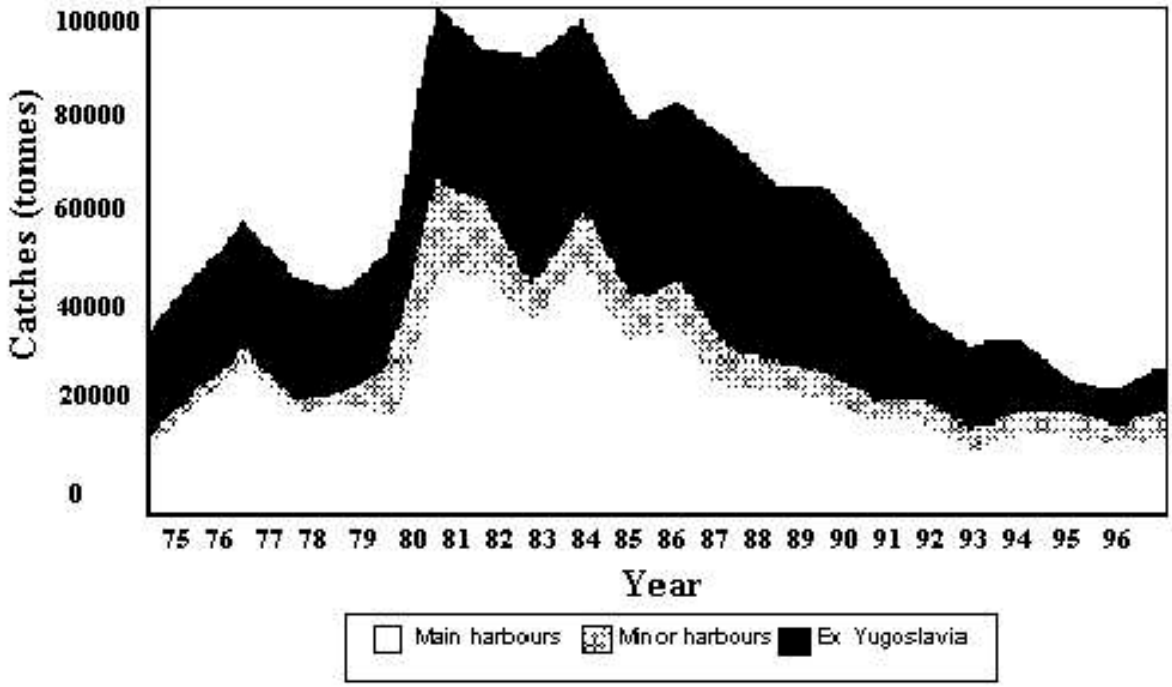

Figure 4. Sardine: catches in the main Italian ports, in the minor ones and in those of the ex-Yugoslavia (from Cingolani *et al*., 1998).

Sardines represent the dominant species with 430000 – 470000 t biomass, while anchovies show more marked fluctuations with a minimum of 60000 in 1987 and 1988 and a maximum of 300000 t in 1995 – 1996. It is estimated that in the North Adriatic 60% of all Adriatic pelagic biomass is present, in the South Adriatic only 15% of anchovy and sardine biomass can be found.
In the last ten years, using acoustic methodology, it has been possible to confirm a considerable increase in pelagic biomass throughout the Adriatic; the population which has experienced major growth is the anchovy which, as previously mentioned, has reached 300000 t, an increase of 5.4 over 7-8 years (Anonymous, 1997).
The increase in the anchovy population did not cause, as was previously thought, a decrease in the sardine population, the latter remained stable even showing a slight increase. From this it would seem that the anchovy population has joined that of the sardine. We can no longer consider as automatic the assertions which were given emphasis in the past, that the two

populations, anchovy and sardine, were alternative in the Adriatic and in other areas of the Mediterranean.
Future research will better be able to evaluate these phenomena and maybe provide further information on the contraction and decrease of pelagic resources which can not be attributed to fishing activity.
The Research Groups of Fano (coordinated by Piccinetti) and Bari (coordinated by Marano) which used the classic eggs and larvae method (Smith and Richardson, 1977), supplied data which confirmed the marked fluctuations in the Adriatic anchovy population, this is in agreement with results obtained by other researchers using different methods to research the same issue.

Figure 5. Sardine: mid year biomass projections by CEDA software, using different fishing mortality rates (F) and levels of recruitment (from Cingolani *et al*., 1998).

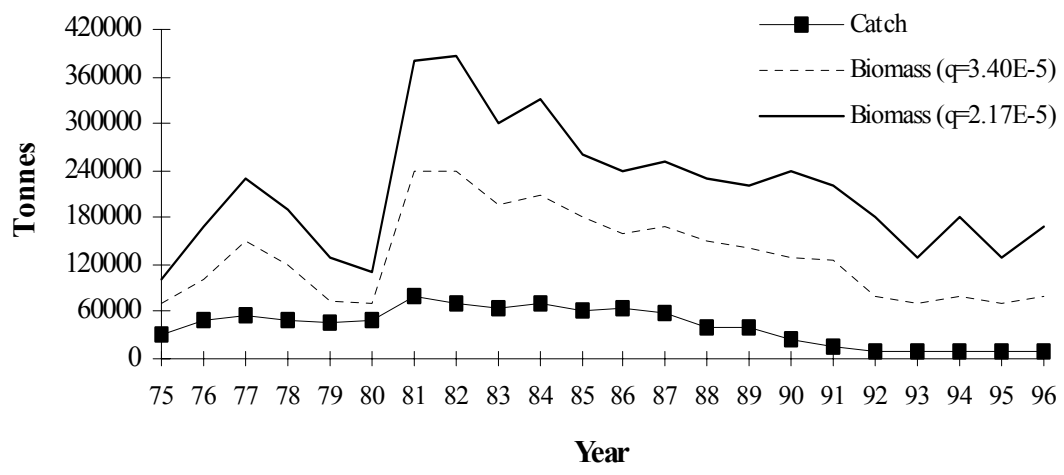

Figure 6. Sardine: catches and mid-year biomass estimated by DeLury “ad hoc” method.

For the Central and North Adriatic the Fano Research Group observed a peak in 1977-1978; in spite of some fluctuations, the situation remained stable until 1985 with a collapse between 1986 and 1988 followed by a recovery in recent years (Piccinetti, personal communication, 1998) (Figure 7).

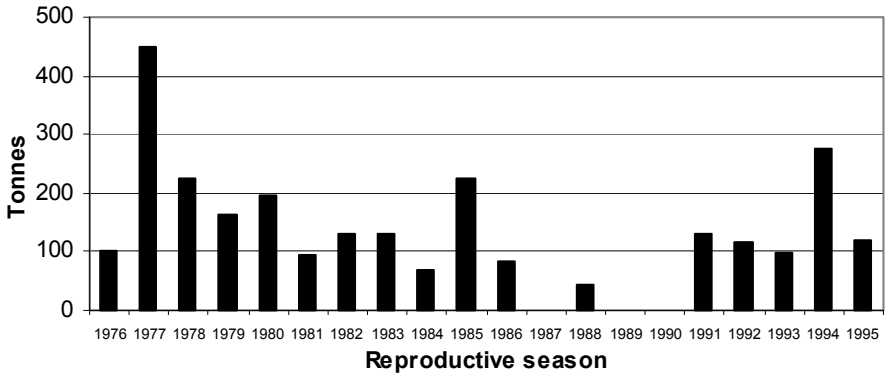

Figure 7. - Anchovy: biomass variations in the North and Central Adriatic Sea.

The stock assessment in the South Adriatic which began in 1984 recorded relatively low values for the eighties, from 1990 – 1996 a marked increase was noted (7-8 times), this was also ascertained by evaluation using the acoustic method (Marano *et al*, 1998).
Research on *S. pilchardus* resources showed greater stability, although over the years the levels oscillate, there are no signs of collapse or marked decrease (Fig. 8).

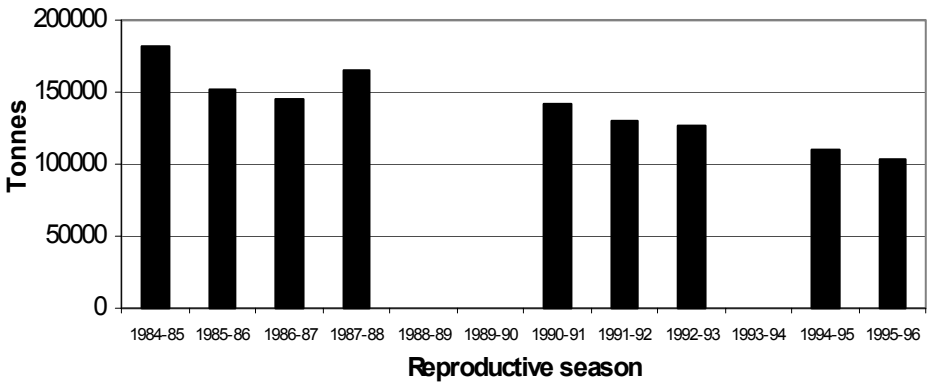

Figure 8. Sardine: biomass variations in the South Adriatic Sea.

In this area the density of the sardine has always been notably greater than that of *E. encrasicolus,* however from the early years until the present day, the trend has been a steady reduction of the stock by as much as 40% (180000 t to 105000 t) this is compared to a massive increase in the anchovy stock size (Figure 9).
Taken as a whole, the research carried out using the various methods to evaluate clupeiform biomass (eggs and larvae survey, echosurvey and population dynamics) showed the same

trends where temporary fluctuation in stock size is concerned, even if in some cases the absolute biomass values were different (however, the index of reliability in these cases was always high).

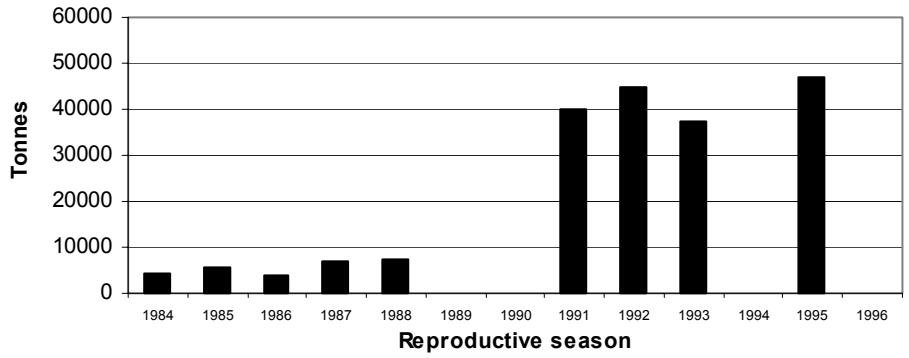

Figure 9. Anchovy: variations in the South Adriatic Sea.

The trend in biomass evaluated over the years is confirmed by all the research groups, whatever the assessment method used for research. In some cases (South Adriatic) biomass evaluations for anchovies appeared to coincide (echosurvey and eggs and larvae survey methods). In other cases estimated biomass seemed dissimilar because they referred to areas of different dimensions compared to those investigated by the research groups.

Between 1984 and 1988 research was also carried out by another renowned scientific institute, the Zoological Station of Naples, coordinated by Bruno Scotto di Carlo in collaboration with Patrizia Mascellaro and Vincenzo Tramontano. The dramatic fate of these renowned researchers is known*. They used to carry out small pelagic stock assessment in the Gulf of Naples by the eggs and larvae method and also studied the relationship between the qualitative and quantitative zooplankton composition and the density of clupeiform eggs in the southern Thyrrenian Sea. (Scotto di Carlo, 1988).

Studies concerning the issue of small pelagic resources have also been carried out by other scientific research centres, some of which have undertaken to study above all the interrelation between the environmental parameters, phyto-zooplankton and clupeiform egg density in reproduction areas.

The Research Group of Genoa, coordinated by Della Croce, estimated clupeiform egg density between the years 1985 – 1996 in the pilot area of Chiavari, the results showed considerable fluctuation during this period. The least abundant species where the number of eggs is concerned proved to be the sardine, the eggs and larvae of which were found from October to March with a maximum in December, the average number of eggs gathered, with reference to all the years, was 19.9 eggs/m^2. From May to August and above all in June, the eggs of the anchovy could be found, the average for the period 1985 – 1996 was 70 eggs/m^2, the highest number was recorded in 1986 when the density was 135 eggs/m^2. A marked variability in the number of eggs deposited during the years was also noted as can be deduced from the high values of the standard deviation (Petrillo *et al.*, 1998).

* They were shipwrecked (Editor's note)

On the contrary the number of *S. aurita* eggs found from June to August was very high, peaking in July, the average annual egg density was 96.1 eggs/m^2, higher therefore than that of the anchovy.
The results of the studies carried out on the correlation between the number of eggs per year from the samples (anchovy in particular) and the environmental parameters considered (excluding temperature), did not allow for any particular interrelation to be ascertained. It is, however, of fundamental importance that the existence of an inversely proportionate relationship between egg density and the extent of the surface water temperature range was observed. It is reasonable to suppose that constant temperatures, within a restricted range, stable salinity levels and water transparency represent requisites for the favourable development of the reproductive season of anchovies. However the high egg density recorded in several years, (1986, 1991 and 1993), cannot only be linked to thermo-saline influences, rather this phenomenon should be related to the combined action of several factors, environmental and biological.
The study carried out in the Ligurian Sea also demonstrated that the density of the cladoceran *Penila avirostris* Dana, the favoured source of nutrition for the anchovy, was high in the same years that the egg density for *E. encrasicolus* peaked. This research allowed for the creation of an important data bank on environmental parameters (temperature, salinity, transparency, rainfall, currents, availability of food) of the clupeiform reproduction areas in Liguria. These historical data are extremely important for the interpretation of phenomena such as collapse or excessive increase of anchovy eggs and larvae density.
The Research Group of Trieste, coordinated by Specchi, has carried out research concerning the ecology of *S. pilchardus* and *E. encrasicolus* in the North Adriatic and in the Gulf of Trieste. Studies on the large quantity of data collected from 1984 to 1996 have provided some extremely interesting information on the reproduction of anchovies and sardines in the Adriatic. Sardines reproduce in the winter in the deeper, central zones of the North Adriatic and migrate towards the trophic coastal areas in the spring. In these coastal areas some sardine eggs can be found although this is the end of the reproductive period. Therefore in order to estimate sardine biomass using the eggs and larvae survey, it is necessary to carry out the assessment from October to March in the central areas of the mid to North Adriatic.
Anchovies also spend the winter offshore, however reproduction occurs near the coast during the summer months, (Specchi *et al*., 1998). For the anchovy, the coast is a reproductive and trophic zone, this is demonstrated by the close correlation between the zooplankton standing crop and the number of eggs, with maximum levels in shallow water (20 – 25 m) and minimum levels in deeper waters.
The studies carried out by the Gulf of Trieste research centre, which analysed data collected over twenty years, show marked quantative cyclicity in the number of eggs, with maximum numbers at the end of the 1970s and minimum levels in the 1980s the latter probably resulting from the appearance of large numbers of the jellyfish *Pelagia noctiluca* Surir and of mucilage. Significant correlation between the number of anchovy eggs and the cladoceran *P. avirostris* has also been observed in this area; it seems that the substantial cladoceran biomass during the summer months can directly influence the quantity of eggs spawned by each individual reproducer or the number of anchovies in reproduction. The correlation could also be due to favourable environmental conditions, the swarming of the cladoceran and egg release. In 1991 when the presence of *P. avirostris* was negligible, there was a great scarcity of anchovy eggs.

The ICRAM Research Group, coordinated by Giovanardi, carried out research to appraise pelagic resources in the Tuscany-Lazio, Ionian and Sardinia areas as well as studies concerning the conditions of anchovy larvae in order to identify the processes which determine recruitment variability. Through these investigations it was possible to highlight the fact that the waters facing the Po river delta represent an environment which favours the survival of anchovy larvae for a combination of factors: increase of primary production and stability of the water column due to the fresh water inflow. However, it was not possible to demonstrate any correlation between availability of nutritional resources and larvae survival.
The following information on estimated biomass was obtained using simulations of DEPM (Daily Egg Production Method) application for areas considered poor due to low clupeiform density. Assessment of the Tuscany-Lazio area showed low biomass, less than 10000 t, almost exclusively made up of sardines. For the Ionian area, estimated biomass evaluation proved problematic due to the scarcity of eggs; altogether anchovy biomass was less than 2000t, while the sardine population could be estimated at around 7000 t. Along the Sardinian coast clupeiform egg collection was also difficult because of the low egg density, at the most biomass could be estimated at a few thousand tonnes, predominantly sardines (Giovanardi, 1998; Giovanardi *et al*., 1998).
The Research Groups of Genova, Mazara, Bari, Ancona n° 2 and Fano are currently involved in biological research on small pelagics for the period 1998 - 2001. Stock assessment using acoustic methods will be extended out of the Adriatic to include Sicilian waters and the Sicily Channel, involving the CNR (National Research Council) institute in Mazara del Vallo, coordinated by Mazzola. The Research Group in Ancona will carry out research using the population dynamics method in a limited area of the Adriatic. The Research Groups which so far have applied the eggs and larvae method have planned research using the DEPM. Methodological support for statistical elaboration is being provided by the polytechnic of Milan (coordinated by Gatto), as well as histological research by the University of Camerino (coordinated by Polzonetti) and the University of Genoa (coordinated by Mandich).
It can therefore be deduced that research has a fundamental role for more rational management of small pelagic resources. At national but above all at Adriatic level, clupeiform fisheries are significantly important both economically and for employment. Furthermore, the processing industry is particularly closely associated with this sector of fisheries.
Consequently it is necessary to have data available from the research carried out on the assessment of catchable resources. Thus the development of the sector can be planned while protecting the resources according to the natural fluctuations in biomass over the years.

3. Summary

Research on anchovy and pilchard stock assessment in the Adriatic Sea (between 1984 and 1996) was reported. Several operative research laboratories used various methods (echosurvey, eggs and larvae survey, population dynamics) in order to estimate the biomass.
All the methodologies demonstrated considerable biomass fluctuation over the years, in particular where the anchovy is concerned, this species strongly decreased from 1986 – 1988 and has increased in recent years. The pilchard stock seems to be more stable and the biomass fluctuations were less significant.

The consistency of clupeiform populations seems to be connected to recruitment success. Recruitment represents a large proportion of the populations, the influence of fishing mortality (30% increase or decrease) seems to be very small. The importance of the relationship between food availability (*Penilia avirostris*) and egg density in the spawning areas was demonstrated by some research, (Research Groups of Genoa and Trieste).

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