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GENERAL FISHERIES COUNCIL FOR THE MEDITERRANEAN

A REVIEW OF THE STATE OF THE FISHERIES AND THE ENVIRONMENT OF THE NORTHEASTERN MEDITERRANEAN (NORTHERN LEVANTINE BASIN)

by

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PREPARATION OF THIS DOCUMENT

Two previous issues of GFCM Studies and Reviews (Numbers 63 and 64) provided broad reviews of recent changes in the fisheries and oceanography of the Black Sea and Mediterranean (Number 63), and made it clear that dramatic changes appear to be happening that were predominantly a consequence of two main anthropogenic factors: overfishing, and runoff of pollutants, notably nutrients, from the catchment areas of these semi-enclosed seas. The second of these reports (Number 64), reported in more detail on recent events and current status of the three main water bodies of the Black Sea system: the Azov Sea, the Black Sea proper, and the Sea of Marmara.

The present document represents the extension of the same methodological approach which combines fishery and oceanographic-environmental information in a single volume, for the Levant basin.

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1. INTRODUCTION

The state of the marine environment of the northern Levantine Basin in terms of the present understanding of the physical processes, production capacity, pollution, and fisheries potential are reviewed.

The eastern Mediterranean, and in particular the Levantine Basin, is only recently emerging from a state of relatively poor data coverage and scientific understanding to become a better known part of the world ocean. These developments have been made possible by multidisciplinary studies motivated by the needs of the surrounding countries and a developing international cooperation. Especially with regard to the general circulation, a significant leap has occurred in recent years in recognizing the complexity of the internal processes and the role of eddies and jets in determining the physical, chemical and biological characteristics of a particular region. Many of these new results are summarized in this review.

Section 2 reviews the regional oceanography as a basis for the following sections. The state of pollution of the northern Levantine Basin is explored in section 3, and the state of the fisheries is presented in section 4.

2. REGIONAL OCEANOGRAPHY

The Levantine Basin is one of the major basins of the eastern Mediterranean lying to the east of the 27°E longitude bounded by the coasts of Libya, Egypt, Israel, Lebanon, Syria, Turkey, Cyprus and part of the Cretean arc (Figure 1). In the subsequent discussions the northern Levantine Basin refers to the area lying north of the 34°N latitude. The remaining portion is termed the southern Levantine Basin.

2.1 Bottom Topography

The Levantine Basin, with a volume of 7.5 x 10 km and maximum depth of 4 300 m is the second largest basin of the eastern Mediterranean, the other three major basins being the Ionian, the Adriatic and the Aegean. Most of the shelf areas of the Levantine Basin are relatively narrow and deep so that abyssal depths are reached within 10-15 km offshore. An important exception to this characteristic is the shelf region surrounding the mouth of the Gulf of Iskenderun.

The major bathymetric features of the basin at large are, the Herodotus Abyssal Plain (3 000 m), the Lattakia (1 000-1 500 m), Cilician (1 000 m), Antalya (2 000-3 000 m) and Rhodes (4 000 m) Basins, the Hellenic Trench (3 000-3 500 m), the Mediterranean Ridge (2 500 m), and the Anaximander (1 500 m), Hecateus and Eratosthenes (1 000 m) Seamounts (Figure 1). The relatively shallow Lattakia and Cilician Basins communicate with each other through a narrow channel of 700 m depth located nearly midway between the sill extending from the northeastern tip of Cyprus to the mouth of the Gulf of Iskenderun.

2.2 Atmospheric Context

The variability of meteorological conditions is one of the distinguishing characteristics of the eastern Mediterranean. This is because the region is a pathway for extratropical cyclones during winter and spring. On the average, about 51 depressions impinging on the Levantine and the Aegean per year bifurcate in such a way that nearly 28 of them pass over the Levantine, the remaining 23 taking a northerly route over the Anatolian Peninsula (Reiter, 1975; Mediterranean Pilot, 1976; Karein, 1979; Brody and Nestor, 1980; Ozsoy, 1981).

In winter westerly winds dominate, while in summer and early autumn winds are generally from the northwest because of the northerly Etesian winds of the Aegean (Mittelandse Zee, 1957; Brody and Nestor, 1980). Sufficiently strong sea-breeze systems also modify the mid-latitude westerlies in summer and autumn.

Additional space-time variability is introduced into the region because of the coastal land topography. In the northern Levantine Basin a local northerly wind regime, the Poyraz, has similar features to the Mistral of the northwestern Mediterranean and the Bora of the Adriatic Sea. This wind system is often generated or enhanced by cyclones, and dry and cold outbreaks of the continental air masses during the winter and spring, and is intensified while passing through the various valleys and mountain passes of the Taurus mountain range along the southern Turkish coast. Because of the spatial inhomogeneity in the intensity of the Poyraz, considerable wind-stress curl is generated over the northern Levantine Basin. During summer a similar wind system of katabatic origin also exists.

The Poyraz winds as well as the northerlies from the Aegean transport dry air of the upper atmosphere to the northern Levantine Basin. The annual average humidity is about 65% but can drop to values as low as 2% during the Poyraz. The hourly wind speeds of the Poyraz can reach up to 36 m/s and the resulting mixing and evaporation lead to rapid cooling of the surface waters (Ozsoy and Unluata, 1983). The significant buoyancy losses generated by the cold and dry outbreaks have been recognized as the predominant source for the formation of the Levantine Intermediate Water (Wust, 1961; Morcos, 1972).

During summer the sea-breeze becomes an important aspect of the meteorology of the Levantine Basin, especially in the northern areas where the inertial frequency nearly coincides with the diurnal frequency. The other regional wind of the Levantine Basin, the Sirocco, is mostly effective in the south.

2.3 Dynamics

Very little was known until recent years about the physical oceanography of the eastern Mediterranean in general, and the northern Levantine Basin in particular. The insufficiency of the previous data-sets, primarily reflecting the patchiness of the data and poor resolution, has precluded the understanding of a coherent picture of the circulation and the formation and the dispersal of water masses (Unluata, 1986; Malanotte-Rizzoli and Hecht, 1988). The basis of the past schematizations of the general circulation of the

Mediterranean at large involves geostrophic calculations based on specific cruises, distribution of water masses and pooled historical data (Malanotte-Rizzoli and Hecht, 1988 and references cited therein). However, in spite of the poor resolution and synopticity of the previous data-sets, some of the crucial elements of the general circulation of the Levantine, such as the Rhodes gyre (see below), were inferred correctly.

As a result of a recent international cooperative research programme entitled POEM (Physical Oceanography of the eastern Mediterranean), a new picture of the dynamical structure and the variability of the eastern Mediterranean is emerging (Malanotte-Rizzoli and Robinson, 1988; Ozsoy, Hecht and Unluata, 1989; Robinson et al., 1990; Ozsoy et al., 1991). This new and definitive phenomenology of the eastern Mediterranean is based on the data obtained during 1985-87. Additional cruises carried out in the Levantine Basin in 1985-88 have provided valuable information on the space-time variability of the circulatory features of the Basin. A synthesis of these results, as they apply to the Levantine Basin in general and the northern Levantine in particular, is presented in this report.

A wide spectrum of spatial scales characterize the circulation of the Levantine Basin. Because of the primarily synoptic coverage of the recent cruises with a half-degree grid station network, most of the POEM data and the other experiments in the Levantine Basin contain information on the basin and sub-basin scales. However, the mesoscale and the sub-mesoscale structures, as characterized by the first baroclinic radius of deformation of the order of 10 km, have also been identified in recent surveys and will be discussed later.

2.3.1 General Circulation

The general circulation of the Levantine Basin based on the results of POEM and other recent surveys has been discussed in detail by Ozsoy, Hecht and Unluata (1989), The POEM Group (1989), Robinson et al. (1990) and Ozsoy et al. (1991). For the present purposes it suffices here to consider selected results.

Displayed in Figures 2a and 2b is the surface circulation in the Levantine Basin during October-November 1985 and March-April 1986. These maps of the dynamic height anomaly are referenced to a level of 800 decibars and are derived from the data collected during the joint cruises of R/V SHIKMONA of the Israel Oceanographic and Limnological Research and the R/V BILIM of the Institute of Marine Sciences of the Middle East Technical University (IMS-ETU) in conjunction with the POEM programme (Ozsoy, Hecht and Unluata, 1989). For the Levantine Basin, the period of the first cruise corresponds to the summer and the second to the winter (Hecht, Pinardi and Robinson, 1988), respectively referred to as ON85 and MA86. The following inferences can be drawn from the maps of surface circulation:

- The general circulation consists of a series of cyclonic and anticyclonic sub-basin scale gyres interconnected by jet-like currents.

- There exists four major gyres called the Rhodes, the West Cyprus, the Mersa Matruh and the Shikmona. These are permanent features of the circulation. The Rhodes and the West Cyprus gyres are cyclonic and are located in the north-western part of the Basin. The other two gyres are anticyclonic, the Mersa Matruh being situated in the southwestern and the Shikmona in the southeastern part of the Basin. A comparison of Figures 2a and 2b indicates that the temporal variability of the features include shifting of the centres of the gyres, deformation and undulation of their boundaries.

- The North African Current appears to enter the Levantine as a mid-basin jet, called the Central Levantine Basin Current (CLBC), flowing eastward between the Rhodes and the Mersa Matruh and the Shikmona gyres. CLBC is also a permanent feature of the circulation.

- On its arduous route, CLBC bifurcates several times, with the number and the location branch points varying in time:

In ON85 the first bifurcation takes place near the western part of the basin, one branch turning south to encircle the Mersa Matruh and the other flowing along the southern reaches of the Rhodes gyre. The latter branch bifurcates again between the Rhodes and the West Cyprus gyres. One branch turns north along the rim of the Rhodes gyre and encircles it while the other continues along the southern rim of the West Cyprus gyre and bifurcates to the southwest of Cyprus. After this last bifurcation, one branch CLBC flows northward, eventually turning west and joining the westerly flow along the southern Turkish coast, while the other branch continues east and later turns southward to encircle the Shikmona gyre.

Intense meandering of CLBC appears in MA86. The bifurcation near the southwest of Cyprus ceases to exist.

- Another permanent feature of the general circulation is the meandering flow along the southern cost of Turkey, called the Asia Minor Current (AMC). This current is not well pronounced in the circulation maps shown in Figures 2a and 2b partially because of its weakness when the data were taken and partially because of the spatial resolution. In order to display AMC, reference is made to the surface circulation for July 1988 as shown in Figure 2c. A coherent and intensely meandering AMC is evident.

- The dramatic differences between the circulation patterns in Figures 2a-2c, especially with regard to AMC, are indicative of interannual variability. Indeed, during the period 1985-88 there is no evidence of inflow into the Cilician Basin from east of Cyprus until 1987. In 1987 transport into the Cilician Basin takes place (cf. section 2.4.1), to be followed by a coherent AMC.

- Two recurrent features of the general circulation are the Anaximander and the Antalya anticyclones. The former appears to be intimately associated with the Anaximander Seamounts. Both anticyclones are present in ON85 while only the Antalya eddy survives in MA86. In other surveys these two eddies are found to change their locations and shape, interact and, in particular, coalesce at certain times to form one single anticyclone (Ozsoy et al., 1991). The time-scale of persistence of the Antalya eddy seems to vary between six months and a year.

- The analysis of the recent experiments indicate significant vertical structure. The eddy centres shift and some of the anticyclonic circulations intensify with depth relative to others which become weaker (Ozsoy, Hecht and Unluata, 1989; Ozsoy et al., 1991)

The various features of the general circulation are shown in Figure 2d.

An important observation with regard to the present discussion is the increased turbidity and the many visual sightings of seabirds, squids and dolphins near the Rhodes gyre. Light penetration measurements indicate higher extinction coefficients (0.2-0.5 m) in the upwelling zone of the Rhodes gyre as compared to the warm core Antalya eddy (0.01-0.1 m).

2.3.2 Mesoscale motions

Mesoscale and the sub-mesoscale structures are characterized by the first baroclinic radius of deformation, which is of the order of 10 km in the Levantine Basin. These motions have been identified in recent surveys, but much remains to be done in understanding these features that evidently affect the biogeochemistry of the Basin by a significant amount.

In the northwestern Levantine Basin, meandering frontal crossings with temperature changes exceeding 1°C within a distance of 10 km have been identified at the peripheries of the cyclonic centres including the Rhodes gyre (Ozsoy et al., 1986). To the north of this broad cyclonic region, the frontal zone partially extends parallel to the coast and separates the shelf seas from the deep ocean water masses. Salinity is reduced along the frontal zones through mixing with the underlying minimum salinity waters. In most of the region phosphate is distributed uniformly and increases only with depth. In contrast, significant increases in phosphate concentrations near the frontal zones are observed. Strong interleaving is inferred from T-S diagrams. These characteristics are typical of oceanic fronts (Bowman and Esaias, 1978).

Intense mesoscale eddies and other features have been detected in especially designed measurements with adequate resolution (Robinson et al., 1987; Leslie and Robinson, 1990). The mesoscale features with or without surface signature appear with horizontal scales of the order of 5-6 times the first internal radius of deformation and vertical scales of 50-400 1m. The mean transports are masked because of the predominance of the intense, isolated and persistent eddies, jets and filaments, the small mesoscale eddies being imbedded in the larger-scale jets and filaments. Over a time-scale extending from six months to a year, the eddies observed in the southern Levantine Basin are nearly stationary with no apparent westward propagation, but change intensity and shape (Robinson et al., 1988). The same appears to be the case in the northern Levantine Basin except for the westward propagation of the anticyclonic eddies in the Cilician Basin at certain times. Structurally, the small mesoscale features exhibit strong shear in the vertical and appears to be intensified at LIW level where currents up to 20-30 cm/s are detected. Within the jet flows near the surface, geostrophically computed currents are as high as 30-40 cm/s (Robinson et al., 1987 and 1988; Ozsoy et al., 1989). Near-surface geostrophic motions are associated with larger structures than the small mesoscale features.

2.3.3 Shelf seas and coupling with the deep ocean

In the Levantine Basin, current meter measurements of sufficient duration are virtually non-existent. The only long-term current measurements (up to 5 months with small data gaps and 2.5 months with no data gaps) are reported by Unluata et al., (1978, 1980), Ozsoy and Unluata (1983). The existence of a mean westerly current along the southern Turkish coast of the order of 10 cm/s is confirmed in these measurements which were carried out on the shelf areas of the northern Cilician Basin. It is also found that the mean flow is considerably reduced at locations where the coastline is relatively rugged, reflecting topographic steering by the bathymetry of the relatively deep coastal waters rather than vortex formation in the lee of the headlands (Unluata et al., 1983).

Even though the aforementioned measurements were carried out on the shelf, they reflect, in particular, the motions in the Cilician Basin proper, because the shelf is narrow and deep and, therefore, strongly coupled to the dynamics of the deep water (Unluata, 1982). The outstanding result of these observations is the dynamism displayed by strong reversing currents (Unluata, et al., 1978, 1980; Ozsoy and Unluata, 1983). The observed fluctuating currents (of up to 45 cm/s) overwhelm the mean flow (of 10 cm/s). They contain both high (above diurnal) and low (below diurnal) frequency components. The along-shore component of the currents is dominated by the low-frequency motions, and the less energetic cross-shelf component is dominated by the high-frequency oscillations. Energy spectra of the low-frequency components contain a very sharp peak at 16d, followed by peaks at 40d, 10d, 6d, and 4d periods. Along-shelf currents and local wind-stress during the measurements do not appear to be strongly correlated in the low-frequencies. Considering the non-uniformity of the wind fields in the Cilician Basin, lack of immediate correlation with local wind-stress is not unusual, although the distribution of regional winds are expected to play an important role in exciting the low-frequency motions.

Theoretical studies indicate that the low frequency motions, with 16d and above periods, can be the manifestations on the shelf of the resonant topographic Rossby waves propagating in the interior Cilician Basin. The motions in the Cilician Basin are shown to drive the shelf motions, and they are, therefore, expected to be intensified at the resonance frequencies of the topographic Rossby waves (Unluata, 1982). The oscillations below 16d period appear to be shelf waves strongly influenced by the baroclinicity and the coupling due to the variable depth.

Concerning the high-frequency components, the most significant oscillations are found to be the diurnal (24h) and the inertial (20.4h at 36°N). The diurnal oscillations are attributable to the strong sea-breeze system that prevails during summer and autumn (Ozsoy and Unluata, 1983 and references cited therein). The closeness of the diurnal and the inertial periods makes possible the near-resonant tuning of the latter by the sea-breeze forcing.

The space-scales of the various motions discussed above are as follows. The first resonant mode of the barotropic Rossby wave's wavelength is of the order of the Cilician Basin's width, viz., 100 km. The first mode of the barotropic shelf wavelength scale is the shelf width 15-20 km. The length-scale of the baroclinic oscillations is the internal radius of deformation of O (15 km). The length-scale of the inertial-internal oscillations are found to be nearly three times the internal radius, i.e., 45k m (Unluata, 1983).

It is known that mesoscale eddies, meandering boundary currents and other processes of the deep ocean greatly influence the motions over the shelf areas (Smith, 1983). Topographic shelf waves may receive energy from eddies impinging onto the shelf areas. Some of the dynamical features of the shelf seas, such as upwelling and shelf/slope fronts, coastal currents with separated vortices, may have serious implications with regard to cross-shelf exchanges with deep waters of heat, momentum, salt, plankton, nutrients and various chemical substances, including pollutants. Such exchanges can crucially affect biological productivity, larval transport, recruitment, chemical transformations, global fluxes of materials and pollution (Smith, 1983; Brink, 1987; Brink et al., 1990, and references cited therein).

It has already been pointed out that, excluding the Gulf of Iskenderun area, the shelf regions in the northern Levantine Basin are narrow and the deep waters are reached rapidly (Figure 1). Consequently, a strong coupling between the shelf and deep water processes is anticipated. On a dynamical basis, the study by Unluata (1982) provides evidence to this effect, both theoretically and experimentally. It is shown that the low-frequency motions are intimately related to what happens off the shelf, and a shelf study that neglects coupling to the deep water and considers only the locally driven motions cannot be fully satisfactory. This aspect of coupling for narrow and steep shelf has been demonstrated for different oceans by Allen (1973, 1976) and Allen and Romea (1980) for both barotropic and baroclinic motions.

Similar results are demonstrated theoretically by Unluata et al. (1985) for steady circulation in the Cilician Basin. It is shown that the motions off the shelf provide additional forcing to the shelf waters, but they are not forced by the wind-driven alongshore flow on the shelf. However, the motions generated by the interior Cilician Basin flow are only concentrated near the shelf edge, because they cannot fully penetrate into the shelf area due to the vorticity insulating effect of the steep shelf. Similar situations have been reported for wide shelf regions rapidly joining to abyssal depths (Wang, 1982; Csanady and Shaw, 1983). Depending on the north-south profile of the current entering from the eastern boundary of the Basin, a net transfer of mass of O (shelf width/basin width = one-tenth) is found to be possible. This transfer is significant in comparison to the flows over the shelf, but insignificant in terms of the flows in the Cilician Basin proper.

In view of the strong coupling of the shelf and the deep waters in the northern Levantine Basin and the variety and dynamism of the motions in the deep waters, the existence of yet unexplored, though crucially important, interactions are anticipated.

In the northern Levantine Basin there is a wealth of time- and length-scales, extending from days to months and micro-scale to mesoscale to gyral scales, and reflecting the dynamical regimes of inertial-internal oscillations, shelf waves, topographic Rossby waves, baroclinic bottom trapped shelf motions, a meandering Asia Minor Current and the associated eddies, the formation of LIW and associated mesoscale processes, and fronts.

2.4 Water Masses

The major water masses existing on the scale of the Levantine Basin are: (a) the Atlantic Water (AW), (b) the Levantine Intermediate Water (LIW), and (c) the Deep Water (Wust, 1961; Hopkins, 1978).

The vertical profiles of salinity and temperature shown in Figures 3 and 4 are utilized to discuss the existence of the various water masses. These profiles are based on data obtained in the southern Levantine. They are indicative of the state of affairs in the north, and have been chosen simply because they are held on a database with sufficiently long coverage (Hecht, Pinardi and Robinson, 1988). The so called climatological profiles in Figure 3 are averages of the data obtained in 17 cruises over a 6-year span. The seasonal characteristics displayed in Figure 4 are obtained by splitting the database such that, based on the heat storage of the upper 200 m, February-April corresponds to winter, May-June to spring, July-October to summer and November-January to autumn in the Levantine Basin (Anati, 1984).

2.4.1 Atlantic water

The existence of AW is due to the influx of the Atlantic water through the Strait of Gibraltar, and in the western Mediterranean is primarily found within the surface layers with salinities 36.15-37.15 ppt (Morel, 1971). Passing from the Alboran Sea to the regions near and past the Strait of Sicily its vertical extent changes from 150-200 m to 200-300 m (Lacombe, 1974). In the Levantine Basin, it is overtopped by surface waters with higher temperature and salinity, so that its signature is a subsurface minimum in salinity as indicated in Figure 3 (Lacombe and Tchernia, 1974; Oren, 1971; Morcos, 1972).

The salinity minimum as an indicator of the presence of AW exists from late spring to autumn (Figure 4). In this period, AW is overtopped by a warmer and more saline surface layer called the Levantine Surface Water (LSW). The LSW is modified by the surface heating and high evaporative losses (Figure 4); it extends down to 40 m in autumn, with salinity values as high as 39.5 ppt and a temperature range of 16-27.8°C. In winters, the subsurface salinity minimum vanishes primarily because of vertical convective processes (Figure 4).

The salinity and temperature properties of AW in the Levantine Basin vary in time and space, reflecting seasonal and interannual variations as well as the variability generated by the internal dynamics (Unluata, 1986; Hecht, Pinardi and Robinson, 1988; Ozsoy, Hecht and Unluata, 1989; Ozsoy et al., 1991). The depth of the salinity minimum varies between 20 and 100 m at different regions and lies within the seasonal thermocline extending down to 100 m. The salinity minimum can be as low as 38.5 and as high as 39 ppt. It is almost never observed at the centre of the Rhodes gyre because of homogenization of the water mass properties by upwelling. In some years (e.g., 1985-86) the AW appears to enter the northern Levantine Basin as subsurface filaments, primarily following the northwest branch of the CLBC which bifurcates southwest of Cyprus and cannot enter the Cilician Basin in large volumes. In other years (e.g., 1987), the AW enters into the Cilician Basin through the passage east of Cyprus. This event occurs after the appearance of AW pools in the Lattakia Basin and the Gulf of Iskenderun area, accompanied by a series of anticyclones which later propagate into the Cilician Basin. The AW appearing in the Cilician Basin is flushed out within a year by the intensification of the Asia Minor Current (Ozsoy et al., 1991).

2.4.2 Levantine intermediate water

The LIW is a water mass that affects the oceanography of the entire Mediterranean. Its signature is a subsurface salinity maximum (Figure 3) located at 100-250 m depths in the Levantine Basin and yet greater depths of down to 400 m in the western basin. In the Levantine Basin, the LIW is found within the permanent thermocline which extends to a depth of 500 m. Traditionally, a salinity of 39.1 ppt and a temperature of 15.5°C (s;29) have been taken to signal this water mass at its source region. By the time it reaches the Alboran Sea it attains a salinity of 38.4 ppt and temperature of 13°C (Nielsen, 1912; Wust, 1959; Morcos, 1972).

Much is yet to be learned on the exact mechanisms through which LIW is formed. However, the evolution of LIW has been related to the generation of highly saline surface waters under the influence of dry and cold continental air masses during February and March when the sea surface temperature reaches a minimum and is typically lower than the air temperature. Surface waters having a greater density than the waters below are thus generated, and a vertical convective process extending down to 200-300 m commences. In the Levantine Basin an isohaline water down to these depths overlaying waters of lesser salinity during the early spring is a manifestation of the sinking of the heavier surface water (Unluata, 1986; Ozsoy, Hecht and Unluata, 1989).

Being a product of the interaction of the dry and cold air flows with the land formation, the Poyraz winds of the southern Turkish coast are found to create most favourable conditions at three areas along the coast. The intensification of the wind system occurs at the major mountain passages at the Gulf of Antalya, the Cilician Basin and off the Gulf of Iskenderun (Ozsoy et al., 1981). The Gulf of Antalya and the regions to its southwest are well documented as formation areas of the LIW (Nielsen, 1912; Wust, 1959; Ozturgut, 1976; Ovchinnikov, 1984).

The considerable amount of scatter found in the T-S values of LIW suggests the existence of more than one source (Morcos, 1972). Homogeneity in the T-S properties is achieved in going west, indicating the smoothening-out by the differences found in the Levantine Basin due to initiation from different sources and also the differences due to annual variations. As pointed out by Hopkins (1978), the transit times out of the source areas must be sufficiently long for this to happen. Ovchinnikov (1984) shows that the spreading is so slow that LIW can be regarded as nearly being "stale". On the other hand, and contrary to Wust's (1961) earlier claim, Katz (1972) found no seasonal dependence of LIW outflow through the Strait of Sicily, indicating either a continuous generation of LIW throughout the year or a slow spreading of LIW.

Recent experiments indicate that LIW is trapped within anticyclonic eddies (Unluata, 1986; Hecht, Pinardi and Robinson, 1988; Ozsoy, Hecht and Unluata, 1989) and, as a result, the rate at which LIW disperses is expected to be very slow, reflecting the sluggish motion of the eddy field. These observations are consistent with the conclusions of Hopkins (1978), Katz (1972) and Ovchinnikov (1984) as well as the theoretical results concerned with the stirring of a passive tracer in an eddy (Holloway et al., 1986). In addition, Ozsoy, Hecht and Unluata (1989) suggest that LIW may be maintained continuously in the Levantine Basin, even though it may be formed more intensely in the peak of winter. It therefore appears that the multiplicity of sources, the slow spreading due to entrapment in the anticyclonic eddies, and nearly continuous generation throughout the year constitute the basic characteristics of LIW.

Analysis of water mass properties in the region indicates that the AW and LIW are simultaneously found in small patches and filaments within the coarse mesoscale eddy field, and premature conclusions on the abundance of water mass species in the region based on average or climatological water mass properties alone could be misleading. Ozsoy, Hecht and Unluata, (1990) found that LIW spatial distribution is highly correlated with small-scale variability in the stream function field. Moreover, AW intrusion processes are present, and their spatial structure is connected to filaments wrapping themselves around some intense mesoscale eddies (Ozsoy et al., 1991).

2.4.3 Deep water

The deep water of the Levantine Basin is characterized by a temperature of 13.6°C and a salinity of 38.7 ppt, and is found in depths in excess of 700 m (Wust, 1961; Moskalenko and Ovchinnikov, 1965; Hecht, Pinardi and Robinson, 1988). Both the southern Aegean and the Adriatic have been suggested as the source areas for the deep water (Nielsen, 1912; Schott, 1915; Pollak, 1951; Wust, 1961; Miller, 1963). A review of these studies has led Hopkins (1978) to conclude, on the lines of Pollak (1951), that the Adriatic is the main source. Recent results based on tracer studies have shown that the Adriatic is the only source, the Aegean water lying between LIW and DW (The POEM Group, 1990).

2.5 Nutrients and Primary Productivity

In parallel with the development of Mediterranean oceanography, recent decades saw a heightened interest in the definition of the regional oceanographic characteristics associated with chemical/biological processes in the Mediterranean basin. Due to the special environment of the Mediterranean and the significant climatological differences between different regions, the diversity of characteristics is a primary feature of the hydrochemistry within the Basin. Therefore, the attempts to define these characteristics often had to recognize the necessity to distinguish between rather loosely defined, yet justified divisions between oceanographic 'provinces'. Furthermore, the processes leading to the specific hydrochemical distributions were often subtle and their observation difficult; without a better understanding of these underlying physical processes, the hydrochemical features could not be readily interpreted.

Some specific chemical/biological characteristics differentiate the Mediterranean from the rest of the world ocean. A thermohaline circulation (e.g., Hopkins, 1978, 1985), driven by the net negative water mass budget at the air-sea interface, leads to the evolution from the low salinity (~ 36.5) Atlantic waters at the Strait of Gibraltar to the high salinity surface waters in the eastern Mediterranean (~ 39). The sinking of the transformed water in the form of LIW in the eastern Mediterranean then follows a high salinity tongue stretching westward and exiting into the Atlantic Ocean at Gibraltar. The nutrient distribution is probably to a great extent determined by these general features. Data studied by McGill (1965, 1969) and more recent evaluations (Coste et al., 1988) show that the loss of nutrients to the Atlantic Ocean at the Strait of Gibraltar was greater than that supplied by the Atlantic water inflow.

The nutrients depleted by the net loss by Gibraltar exchanges are in part balanced by river runoff. The river discharges in the Mediterranean can at best be characterized as insufficient due to the specific geographical setting; the proximity to a vast desert in the south, the arid climate and increasing use of rivers for irrigation and industries. The eastern Mediterranean is especially poor in river discharges, having fewer major rivers in the western basin which are increasingly being put to human use.

In consequence to the thermohaline circulation and the insufficient supply of the rivers, the nutrient reserves of the Mediterranean are limited, causing it to be one of the world's poorest seas - for example, the phosphate concentration of the Levantine Basin deep waters is only one-sixth of the Atlantic Ocean (McGill, 1965), which in turn is already relatively impoverished compared to other oceans.

As a result of nutrient limitation of primary production, much of the Mediterranean surface water is oligotrophic. On the other hand, even minimal organic activity needs to be supported by new sources of nutrients (other than recycled forms) near the sea surface, and the rather substantial Mediterranean fishery shows that the 'new production' available to the system is sufficient to support a certain level of biological productivity (Dugdale and Wilkerson, 1988).

New production occurs either as a result of terrestrial inputs or due transport of nutrients from intermediate depth reserves to the surface by dynamical mixing processes (McGill, 1965, Dugdale and Wilkerson, 1988). The unique scheme of circulation of nitrogen nutrients in the euphotic zone of the Mediterranean as constructed by Dugdale and Wilkerson (1988) indicates that subtle processes such as the contribution of ammonium and other organic fractions in addition to nitrate, surface advection of particulate nitrogen and detritus become important components in the Mediterranean context because of generally low concentrations of nutrients.

Dugdale and Wilkerson (1988) showed that about 20-40% of the new production in the eastern Mediterranean is due to terrestrial inputs. Surface water fluxes and the terrestrial source intensities of phosphorus and nitrogen (Bethoux, 1981) indicate the relatively small contribution of the Eastern Mediterranean, and in particular of the northern Levantine region, to the overall Mediterranean budget. The effects of 20-40% terrestrial contribution to new production cannot be overemphasized in recognition of the already low terrestrial discharges in the eastern Mediterranean. Dugdale and Wilkerson (1988) also suggest proportionality between new production and fish yield, indicating that a significant part of the fishing potential in the Eastern Mediterranean may be related to terrestrial nutrient discharges.

In spite of the decreasing river discharges in recent decades, it seems that the Mediterranean is not necessarily subjected to a decrease in nutrient inputs. The semi-enclosed geometry of the Mediterranean and a rapid increase in the bordering population as well as in their living standards subjects the Basin to increasing anthropogenic nutrient discharges. Assuming a 3% yearly increase in such discharges, and supported by a box model and a series of recent nutrient measurements, Bethoux (1989) estimated a three-fold new production increase would occur in the Eastern Mediterranean within 50 years from now. Consequently, early in the twenty-first century, Bethoux (1989) expects a drift towards conditions more akin to the Black Sea, i.e., increased new production occurring near the ocean surface, reduced oxygen in the intermediate and deep water, and increased threats to benthic communities. An increase in the deep water nutrient concentrations of the western Basin is reported by Bethoux and Copin-Montegut (1988). Support for the unsteady evolution scenario of the deep waters is given by assessments (Bethoux et al., 1990) of the parallel evolution of deep water temperature in the western Mediterranean within a relatively short period.

The vertical transport of nutrient from the nutrient-rich deep waters to the euphotic zone is one of the primary mechanisms supporting part of the new production, although the already low concentrations found in the deep water set limits on the amount contributed. The subtle mechanisms of the transport of nutrients from the deep to near-surface waters often cannot be identified in detail, and are usually interpreted as combined effects of marine dynamics. Violent forms of vertical transports occur in the deep water formation region at the northern part of the western Mediterranean Basin (e.g., Coste et al., 1972). Another mechanism is associated with the transient vertical transports near fronts, and the role of coastal or shelf-break fronts in biological productivity is relatively well known (e.g., Bowman and Esaias, 1978) as compared to open ocean fronts. In a Mediterranean context, open ocean frontal mixing was shown to be the predominant mechanism for increased production at some frontal regions of the western Mediterranean (Lohrenz et al., 1988a, b).

For the northern Levantine Basin, Ozsoy et al. (1986) obtained continuous samples of temperature, salinity and phosphate at the sea surface, and showed that the relative concentration of phosphate increased near frontal regions adjacent to the various eddies. On the other hand, no significant increases of surface values were observed elsewhere, indicating that the nutricline does not surface in relation to the mesoscale features of the eddy fields. Excluding some confined areas of mixing at fronts, the nutricline generally follows the same depth variations as the pycnocline as shown by Salihoglu et al. (1990) and Basturk et al. (1988).

There is evidence that the shallowing of the nutricline at the centres of cyclonic eddies such as the Rhodes gyre and its extensions also leads to primary production. The chlorophyll-a in the region typically has a deep maximum located at about 1-10% penetration of the incident surface solar radiation (Yilmaz et al., 1988). According to Salihoglu et al. (1990) and Basturk et al. (1988), the raising of the nutricline to within the euphotic zone in the Rhodes gyre leads to a shallowing of the chlorophyll-a maximum together with an increase in the total chlorophyll in these regions. This motivates an increase in the total biological productivity, as confirmed by higher yields of Neuston net hauls (Salihoglu et al., 1990), and visually observed abundance of zooplankton, fish larvae, small shrimp and even larger organisms such as squid and dolphins in the Rhodes gyre region.

The primary productivity estimates for the eastern Mediterranean and in particular for the Levantine Basin are rather rare and quite varied. Most of the measurements have been done for the neritic waters of the narrow continental shelf, and a few measurements exist for the pelagic open sea waters. Berman et al. (1984, 1986) suggest 6-40 g C m y for the open waters of the southeast Levantine Basin, based on the earlier records of Israeli measurements.

The only estimates of primary productivity using chlorophyll-a measurements in the northern Levantine Basin were made by Yilmaz (1986) who quotes 24 g C m y for open waters, and by Gocmen (1988) who indicates seasonal average values of about 25 g C m y for neritic waters and 16 g C m y for the pelagic waters in this region. There appears to be a winter to spring maximum in production and a secondary peak during autumn.

Both Gocmen (1988) and Yilmaz et al. (1988) indicate a 80-150 m depth of the euphotic zone in the northern Levantine Basin based on light penetration measurements. It is confirmed that the deep chlorophyll-a maximum (DCM) is a prominent feature of the oligotrophic waters of the Mediterranean. It appears that the deep penetration of light combined with low concentrations of nutrients in the euphotic zone limits primary production to deeper levels of the water column as compared to other seas. Exceptions to this situation occur only either at the centres of cyclonic eddies or open sea fronts where the nutrients become available at shallower depths.

3. THE STATE OF POLLUTION

3.1 Sources of Pollution

It is estimated that 80-90% of the pollution in the Mediterranean is due to the land-based sources. Atmospheric transport, offshore oil spills and the exchanges with the Atlantic and the Black Sea evidently play secondary roles, but further research is needed to quantify those effects. It is, however, important to note at the outset that the uncertainties in the sources can typically lead to estimation errors of about one order of magnitude in the pollution loads.

Agriculture, industry and tourism-related activities along the coastal zone of Turkey are the most significant among the several countries bordering the northern

Levantine Basin. Population increase, urbanization, greater affluence and faster transport are causing a rapid increase in exploitation of the coastal zone. Textile, petrochemical, agrochemical, agrofood, iron, steel and pulp industries constitute the main industrial activities. Three major ports (Iskenderun, Mersin, Antalya), the BOTA-Yumurtalik pipeline terminal, the Mersin refinery and the Iskenderun terminal for petroleum products motivate heavy tanker traffic in the region.

With the exception of the BOTA pipeline terminal, raw or insufficiently-treated industrial, domestic and agricultural wastes are often discharged directly into the coastal waters and rivers. These land-based wastes and ship traffic constitute the major sources of pollution, a reliable estimate of the contribution from the atmosphere being unknown at present. The sources for a series of selected pollutants in the northern Levantine Basin are given in Table 1.

Table 2 presents estimates of the annual loads of selected pollutants in the northern and southern Levantine Basin and the entire Mediterranean. Table 3 displays the sources and the loads of these substances for the northern Levantine Basin. Estimates of the loads from the atmosphere for a series of heavy metals are given in Table 4.

It is observed in Table 2 that the Levantine Basin receives relatively small amounts of pollution compared with the Mediterranean as a whole. The pollution loads in the northwestern Mediterranean and the Adriatic are estimated to contribute respectively with 33% and 25% to the total load.

It can be inferred from Table 2 that a significant part of the land-based discharges in the Levantine Basin originate from Turkey. The rivers along the Turkish coast carry a total discharge of 36 000 million cm^3 (revised estimate; EIE, 1978), constituting about 6% of the total fresh water input into the Mediterranean. On the other hand, the annual contribution from industrial and domestic discharges into the northern Levantine Basin is estimated to be in the order of 0.44 million cm^3 (UNEP, 1984). Consequently, in the northern Levantine Basin the river-runoff is more than 99% of the total.

Table 3 indicates that river runoff contributes to the various forms of pollution loads, often dominating the overall input. This integrated transport of domestic, industrial and agricultural wastes by the drainage systems leading to the final river mouth sources is an important issue for the Turkish Mediterranean coast.

The following inferences can be made from Table 3 regarding the loading of various materials into the northern Levantine Basin. The dominance of organic matter in river inputs shows the significant influence of the hinterland on coastal pollution. Nevertheless, the importance of agricultural runoff with respect to hard pesticides, the resistance to biodegradation of the organic matter in industrial wastes and localized eutrophication due to domestic wastes should also be borne in mind. Organic matter is introduced at the highest rates from domestic and industrial sources.

The rivers also appear to be the most important sources for detergents, mercury, lead, chromium, zinc and pesticides.

Industrial inputs from oil refineries and terminals are the dominant sources of phenols and mineral oil, while river inputs appear relatively lower, though not negligible. It is evident that mineral oil is by far the most dominant industrial input.

Recent estimates of the suspended sediment input by rivers and other sources (not shown in Table 3) are 1.6 x 10 and 0.8 x 10 t/y respectively (Salihoglu et al., 1986).

It should be noted that the proportions in which the various substances are discharged into the marine environment do not constitute a basis for their importance, and even small fluxes of certain substances may have detrimental effects on marine life. Each substance should be evaluated in terms of the extent to which the medium is affected by it. This should also be kept in mind when comparing land-based sources with other forms of pollution loading. For example, Table 4 indicates that the atmospheric contributions of some heavy metals are by no means negligible within total pollution loads.

It is difficult to assess the oil pollution resulting from the relatively heavy transportation, especially in the Levantine Basin.

3.2 Levels and Distribution of Pollutants

3.2.1 Pollutants in sea water

In the northern Levantine Basin, heavy metals, dissolved dispersed petroleum hydrocarbons, suspended sediment, pelagic tar, and plastic and other litter have received attention as significant pollutants.

The extremely toxic element of cadmium is found to be below detection limits in the northern Levantine Basin.

Total tin is essentially uniform in space with an average concentration of 11 ng/l, a value similar to that found by Hodge et al. (1979) on the US Pacific coast. The Iskenderun iron and steel complex, with a discharge of 3.2 x 10 t, evidently leads to tin concentrations as high as 1 115 ng/l in the vicinity of its outlet (Tugrul et al., 1983; Yemenicioglu et al., 1984). Mono-, di- and tri-methyl tin compounds were only detected near rivers and estuary waters, indicating biomethylation to be the supply mechanism (Salihoglu, 1986). A pilot study on tributyltin, an organotin commonly used in antifouling paints, and its derivatives in seawater have indicated concentrations above the harmless level of 20 ng l in several areas of the Mediterranean (Gabrielides et al., 1990). Significantly higher concentrations have been found in harbours and marinas, among which the Mersin Harbour sample with 936 ng l.

Total mercury concentrations of up to 40 ng/l have been observed in the polluted waters of the bays of Iskenderun and Mersin. This is higher than the 11-14 ng/l reported for the open ocean waters of the northwestern Pacific, 0.2-1 ng/l for the northern Atlantic, 3-22 ng/l for the western Mediterranean and also the values found for the coastal waters of the southern Levantine Basin (Miyake and Suzuki, 1983; Bloom and

Crecelius, 1983; Huynh-Ngoc and Fukai, 1979; Roth and Hornung, 1977), but within the range of the 12-84 ng/l of Kulebakina and Kozlova (1985) for the Ligurian Sea.

In general, the open ocean total mercury levels in the northern Levantine Basin do not differ much from those found in other areas of the world ocean. Mercury anomalies reaching 37 and 50 ng/l have been observed, however, in central areas of cyclonic eddies (Salihoglu, 1986). The increased suspended sediment concentrations (0.6 mg/l) in the same regions (Saydam et al., 1984) cannot explain the presence of high mercury levels since in the open ocean only 3-30% of the total mercury is expected to be bounded to suspended sediments. Consequently, the observed mercury anomalies may be attributed to atmospheric transport (Salihoglu, 1986).

Dissolved/dispersed petroleum hydrocarbons (DDPH) are extensively observed in the northern Levantine, reflecting the presence of oil terminals, heavy tanker traffic and illegal discharging. Extensive studies there indicate DDPH concentrations in the range of 0.05-2.50 mg/l with an average of 0.19 + 0.27 mg/l (Kilic, 1986). Concentrations as high as 6 mg/l have been observed in the Cilician Basin, possibly related to shipping, and 7 mg/l in the Bay of Iskenderun, possibly reflecting the oil terminal related activity. It appears that DDPH levels in the northern Levantine Basin are in excess of those observed in most of the world ocean (Salihoglu, 1986).

Tar balls formed from oil or oily compounds are persistent because of their resistance to biodegradation. In the offshore areas, Balkas et al. (1982a) reported floating tar up to 5 mg/m, which increases to 10-80 mg/m in the coastal seas. The highest tar concentrations in the northern Levantine Basin of 33.4 mg/m in Iskenderun Bay and 2.1 mg/m in the Cilician Basin were found by Saydam et al. (1984), who estimated 66 t of total pelagic tar present in the Bay of Iskenderun during April 1983. A more recent, basin-wide study of pelagic tar distribution in the Mediterranean indicates that the northern Levantine Basin is one of the most contaminated areas (Figure 5), with high concentrations of up to 5.6 mg/m in the Cilician Basin, and 12.9 mg/m in the Rhodes gyre region (Golik et al., 1988). The mean concentrations in Areas I and III (Figure 5) were 1.8 and 1.3 mg/m respectively. This study also seems to indicate a decline in pelagic tar contamination in the region between 1969 and 1987 as a result of more stringent regulations and technological improvements in oil transportation.

The estimated suspended sediment (TSS) inputs into the northern Levantine are given in Table 2. The annual input is 1.7 million t/y and the highest contribution is from rivers with 1.6 million t/y. Based on extensive surveys of TSS distribution in April, June and October 1983 and April 1984, Saydam et al. (1984) have shown that some of the offshore TSS concentrations exceed coastal values. Salihoglu (1986) notes the same trend. Since particles from land sources would sink rapidly before reaching offshore locations (Epply et al., 1983), offshore TSS maxima can only be explained by primary production. Yilmaz et al. (1986) obtained chlorophyll-a measurements of up to 1.0 mg/l which were coincident with the high TSS observations. The open sea biogenic origin of TSS needs further confirmation since the particulate organic carbon and primary productivity of the region is not well known at present.

The background TSS concentrations in the northern Levantine have been estimated as 0.5-1.0 mg/l (Emelyanov and Shimkus, 1972) and more recently as 0.8 mg/l (Saydam et al., 1984).

TSS distribution in the basin shows spatial as well as temporal variability. The relatively higher concentrations observed in the eastern Cilician Basin and the Gulf of Iskenderun area reflect the influence of the Seyhan and Ceyhan rivers. TSS distribution in this region indicates considerable transport offshore by the meandering Asia Minor Current and the eddies (Salihoglu, 1986).

The highest concentrations of plastic and other litter in the northern Levantine are found in the Bay of Iskenderun (Saydam et al., 1984; Bingel et al., 1986), evidently being entrapped by the two mesoscale gyres of the Bay (Akyuz, 1975; Collins and Banner, 1979). Some 10 t of plastic bags; 2.5 t of spherules and 2.5 t of other pelagic material were found in the surface waters of Iskenderun Bay by Saydam et al. (1984), while within the 0-100 m depth the overall estimate was 264.6 t (Bingel et al., 1986). Part of the material on the Turkish coast is found to be transported from Syria, Lebanon, Israel and even from Egypt by the prevailing currents.

3.2.2 Pollutants in marine biota

The series of pollutants examined in the commercially important marine organisms of the northern Levantine Basin include heavy metals, chlorinated hydrocarbons and polyaromatic hydrocarbons.

The mercury levels have been found to be within acceptable limits, excluding those in Upeneus moluccensis and Portunus pelagicus, the concentrations in the former species exceeding the permissible 500 mg/kg (fresh weight) limit. Seasonal variations of mercury in several species were found to be strongly correlated with the periods of application of mercury fungicides, peak rainfall periods and physiological changes in the organisms examined (Balkas et al., 1982b).

Tugrul et al. (1980) and Salihoglu and Yemenicioglu (1986) have reported mercury concentrations of up to 559 + 354, 470 + 277 and 2 503 + 1 209 mg/kg (dry weight) respectively in samples of Mullus barbatus (red mullet), Portunus pelagicus (blue crab) and Upeneus moluccensis (goldband goatfish) caught away from any anthropogenic mercury sources. These high mercury levels in fishery products are either very close to or exceed the permissible limits, and may be indicative of high mercury levels in the estuaries of the Göksu, Seyhan and Ceyhan rivers where the samples were collected (Salihoglu, 1986). Concentrations of chromium, nickel, manganese, lead and cadmium in biota are generally found to be low.

PCB concentrations in some fish and crustacea from the northern Levantine could not be detected in any of the species examined except in Patella caeulea with a maximum concentration of 39 mg/l in fresh weight (Balkas et al., 1978; Basturk et al., 1980).

Basturk et al. (1980) report a t-DDT concentration range of 8-324 mg/l in Mugil auratus in the northern Levantine Basin, which is comparable to that for the North Adriatic (Pitcer et al., 1978; Revelante and Gilmartin, 1975). The same authors also report t-DDT concentration ranges of 9-257 mg/l for M. barbatus, 20-50 mg/l for M. surmuletus and 50-100 mg/l for U. moluccensis.

The data on polyaromatic hydrocarbons (PAH) in marine organisms of the northern Levantine Basin are meagre. Salihoglu (1986) indicates that PAH concentrations in Solea solea, Mullus barbatus and Epinephelus aeneus can reach maximum levels of 12, 15 and 5 mg/kg in dry weight, respectively, and livers of these fishes are more susceptible to accumulation as compared to their flesh. In the Spanish coastal waters, similar results have been found for M. barbatus, Merluccius merluccius, Trachurus trachurus (Albaiges et al., 1984).

3.2.3 Pollutants in sediments

In coastal areas of the Cilician Basin, sedimentary lead concentrations are found to vary in the range of 46-280 mg/kg (dry weight) (Ozkan et al., 1980), maximum concentrations occurring in the highly polluted Mersin Harbour.

The concentrations of copper are reported to be between 21 and 368 mg/kg against an estimated background level of 10-44 mg/kg, the lowest values being observed in the deep sea and the highest in Mersin Harbour (Ozkan, et al., 1980; Shaw and Bush, 1978).

The zinc concentrations in the coastal waters of the Cilician Basin are found to be 107 + 21 mg/kg with a maximum value of 483 mg/kg in Mersin Harbour, the levels otherwise being of the order of the background values.

Tin concentrations also show a maximum of 11 mg/g in the sediments of Mersin Harbour. In other parts of the Turkish coast, the sediments contain background level tin concentrations in the order of 0.5 mg/g (Tugrul et al., 1980; Salihoglu, 1986). The presence of mono-, di- and tri-methyl tin in all of the sediment samples collected in the coastal waters of the Cilician Basin indicate microbial activity (Salihoglu, 1986).

Total mercury concentrations away from land-based sources are in the order of those observed elsewhere in the Mediterranean, but reach values of 131+162 ng/l the Mersin Harbour (Salihoglu and Yemenicioglu, 1986; Salihoglu, 1986). In the organic rich, anoxic sediments adjacent to the domestic waste outfalls of the city of Mersin, methyl mercury is abundant.

Balkas et al. (1978) and Basturk et al. (1980) report the concentrations of total DDTs and metabolites to be in the range 5-26 mg/kg. PCBs were found to be below the detection limits.

At present, petroleum hydrocarbons in the sediments of the northern Levantine are below serious levels. In one case of a crude oil spill in the Gulf of Iskenderun, however, concentrations reaching 1.3 mg/kg have been observed by Salihoglu et al. (1987).

3.2.4 Concluding remarks

The deep waters of the northern Levantine Basin are still relatively unpolluted, since the concentrations of various chemicals, oil slicks along shipping lanes, and litter, though detectable, do not appear to be of major consequence to communities of organisms.

While this is the case for the deep waters, the coastal and shelf seas are affected in varying proportions due to the rapid exploitation of the coastal zone as reflected by growth of the cities, establishment of new settlements, siting of industrial installations and the construction of harbours and tourist facilities.

One of the regions that appears to be critically affected is Iskenderun Bay. The land-based pollution loads emanating from the industrial complexes situated along the periphery of the Bay have generated local degradation of the environment. The entrapment of externally introduced, biodegradation-resistant pelagic litter poses a significant threat to the living marine resources of the Bay.

Eutrophication appears to be a significant problem confronting the coastal zone, especially in the region extending from Iskenderun to Göksu river. The pollution in the Mersin Harbour and in its close proximity has reached alarming levels.

In some commercially important species of fish, highly toxic compounds such as orgonotins and orgonomercurials are found to exceed permissible levels.

In view of the presence of a host of physical processes with various time- and space-scales in the Levantine Basin, the lack of data on the basin-wide distribution of pollutants make it difficult to assess their redistribution by horizontal advection, diffusion, dispersion and vertical convection.

In terms of the basin scale transport, evidence exists on significant amounts of material being transported from the southern into the northern Levantine. The simplest indication is given by the transport into the region of plastic material discharged along the coasts of Egypt, Syria and Lebanon as reviewed above. The periods of increase in the tar balls coincide with those of plastics.

Further evidence for a basin-wide transport is provided by drift-card experiments (Gerges, 1982, personal communication). The drift cards released in Egyptian waters are found on the shores of Turkey and Cyprus. It should be noted, however, that the cross-basin motion of the cards may either reflect an alongshore general circulation pattern or transport by offshore eddies which take part in the general circulation and exchange material with other eddies and gyres.

After the construction of the Aswan dam on the Nile River, the Turkish rivers have become the only major contributors of fresh water into the Levantine. Of these, the Seyhan and Ceyhan, located in the northeastern Cilician Basin have the largest discharges. Recent studies (Salihoglu, 1986) in the northern Levantine and the Cilician Basins have revealed considerable offshore transport of certain substances by the meandering Asia Minor Current and associated eddies. It appears that an anticyclonic eddy located on the shelf off the Gulf of Iskenderun transports material from the Gulf into the Asia Minor Current.

The aforementioned studies also show increased concentrations of metals and petroleum hydrocarbons in central areas of the Rhodes gyre and near-coastal regions in the Gulf of Antalya and to its west. Preliminary analyses indicate that the former appears to be transported in the filaments of Atlantic water and entrapped by the gyral motions. On the other hand, PAH concentrations seem to reflect inputs from the oil traffic, some of which is entrapped by the gyres, the remainder being transported northward by the cyclonic flow. High turbidity and productivity are also observed in the mid-gyre area, as noted earlier (Ozsoy et al., 1986a). The influence of eddies and gyres in these studies are in harmony with those observed elsewhere (Haidvogel et al., 1983) and clearly demonstrate the importance of these motions on the distribution of various substances in the Mediterranean.

The picture that emerges for the northern Levantine Basin is that the substances introduced into the area may have relatively long residence time due to entrapment by the eddies and peripheral features of the Asia Minor Current. The oscillatory currents in the shelf regions may further contribute to this aspect. This is because of the relatively slow shear dispersion that occurs in oscillatory flows with short time-scales (Young et al., 1982). Another aspect of an oscillatory current is that, to a first order in amplitude, the net particle motion over a period vanishes. This feature of oscillatory currents may have serious ramifications in the transport of substances introduced into the sea, because it implies long residence time in the vicinity of the source area, the eventual net transport away from the source occurring under the influence of a local mean current and/or the mean streaming induced to the second order. The influence of induced streaming has been examined by Unluata et al. (1983) for high-frequency oscillations in the Cilician Basin.

It is also anticipated that LIW formation may accompany vertical transports of various substances into the deep waters. The known upwelling processes near cyclonic circulations and open sea frontal processes may generate significant recirculation of matter within the Basin.

4. THE STATE OF THE FISHERIES

4.1 General Information

The Mediterranean contribution to the world fish catch is about 1.8%, yet it constitutes about 5% of the total revenue because of the higher prices of Mediterranean fish. The fish catch is far from meeting the demand in many of the bordering countries, especially during the summer when the coastal population is swollen by tourism. As a result, much of the fish consumed in the Mediterranean is imported from other areas such as the Atlantic Ocean and the Red Sea.

Another important aspect of the regional fishery is its mainly "artisanal" character, requiring considerable manpower either at sea or on land (Charbonnier, 1977). Furthermore, the stocks utilized and market demand are directed towards relatively higher priced demersal fish. The full utilization of small pelagic fish for human consumption is lacking in spite of the limited supplies and unfavourable conditions for further fishery development.

The reasons for low productivity in the Mediterranean are outlined in section 2.5. Without any net effects on biomass, the communication with Red Sea also seems to influence the characteristics of the Eastern Mediterranean fishery. In spite of the unimportant water and nutrient exchanges through the Suez Canal, the decreased runoff of the Nile motivates an increased Lessepsian migration of more Red Sea individuals into the Eastern Mediterranean. The Red Sea emigrants intrude into the environment inhabited by native specimens and compete with them possibly without significantly altering the net production.

Coastal areas of high production are also limited due to the narrowness of the continental shelf in most of the Mediterranean, excluding the exceptionally wide shelf regions such as the Gulf of Iskenderun in the northern Levantine Basin, the Nile delta in the southern Levantine and the shallow Adriatic Sea region. Other exceptional areas arise in the open sea due to new production supported by vertical transports of nutrients (section 2.5), such as in the vicinity of the Rhodes gyre in the Levantine Basin, the Gulf of Lions, the Alboran Sea and the waters off Algeria in the western Mediterranean Basin. Such exceptional areas are indeed oases in the blue Mediterranean desert.

The main Turkish Mediterranean fishing grounds basically overlap with a wide continental shelf region which primarily determines the fishery characteristics.

The fishery resources of the Turkish waters, as in the case of many other countries of the world, are legally open to public access, excluding some coastal lagoons. Experience gained from many fish stocks over several decades has shown that management and regulation of fishery resources in open-access fisheries do not work well when the capacity of the fleet exceeds the self-sustaining ability of the stocks (Clark, 1985, Berkes, 1986). Recent publications on the performance of the best known fisheries in northern Europe indicate that the fishery sizes often exceed recommendations, and sometimes even predetermined quotas. The enforcement of Total Allowable Catches (TACs) failed for many stocks due to fishing over-capacity. Fishery fleets with over-capacity (surplus effort aiming to pay its standing costs) may exploit the stocks out of existence or result in overfishing of the stocks leading to a steady waste of money (Thurow, 1990).

The Turkish Mediterranean coast fishery may be characterized as follows:

- Operation in biologically poor waters,

- Predominant catches of bottom-dwelling species of high diversity including the Red Sea emigrants,

- Landing of relatively high price fish,

- Relatively high number of small boats (of 8-10 m length, usually with about 10 HP inboard diesel engines) operated mostly by two persons,

- High number of recreational (hobby fishermen) boats whose fishing equipment is not exactly known (note: it is assumed that most of these fishermen use hooks and lines, while a few of them may also use gill and entangling nets of varying mesh sizes),

- Small and distinct landing places,

- Bottom trawlers and seine boats of 15-25 m length with engines of 100-150 and more HP. While bottom trawlers are operated by 4-6 men the seine boats need much higher manpower (approximately 16 men),

- The beach seine net is not a frequently used gear in the coastal area. Nevertheless, it has some application along the coastline. Small sized nets are operated by hand. On the other hand, Berkes (1986) notes also a net operated from a boat of 10-15 m length by mechanized means.

Along the Turkish Mediterranean coast, the national fishery fleet exclusively operates within territorial waters. The statistics collected from this fishery are based on questionnaires of the fishermen. Although the statistics collected in this way are often believed not to be strictly reliable, there have been some improvements in the collection of data since 1982.

Data collection from a small-scale fishery with small and distinct landing places on a narrow strip extending several hundred kilometres (as in the case of the northern Levantine fisheries) has inherent deficiencies (Gulland, 1979), due to the tax evasion motives of fisherman and time lags between actual catch date and time of reporting. When reporting seasonal catches, the fishermen may at best have a fair idea on periods of good or poor catches. A general lack of reporting of occasional recreational sport fishing may also be significant.

4.2 Sources of Fisheries Data

The state of the Turkish Mediterranean fishery will be described using two important data sources. First, from statistics gathered from the official questionnaires of the Turkish State Institute of Statistics (DIE) for the years 1968-87, and second, the set of data gathered by a quantitative fishery project of the Institute of Marine Sciences (IMS) of the Middle East Technical University (IMS-METU), sponsored by the Turkish State Planning Office (SPO).

4.3 Fishing Fleet

Information on the size of the fishing fleet is given in the DIE annual bulletins. The number of boats and their horsepower (HP) are given in Table 5 for the years

1968-87. Table 5 will also show that the number of boats fluctuates from year to year. This may lead one to conjecture possible errors in the available statistics. Nevertheless, such information may still be more correct and reliable than the annual yield statistics and their species distribution.

4.3.1 Fishing gear of the fishing fleet

Most of the trawling activity takes place in Mersin and Iskenderun Bays. Some vessels work also west of the Samandagi region. A few (2-4 vessels) work east of Silifke and around Anamur (Figure 6), and the remainder in Antalya Bay and neighbouring waters.

All vessels utilize trawl nets suitable for soft grounds with a very low vertical opening capacity of 60-100 cm. The mouth openings between the wing tips are between 6 and 8 m. The nets are often made from locally produced nylon material.

Until 1981 (1977-80) there was only one seine boat in the region between Mersin and Iskenderun. Strict restrictions on trawling within the 3-mile zone in the early 1980s induced an increase of seine fishing in Mersin and Iskenderun Bays. In a very short time, 6-8 boats, typically with only one seine net set and power block of the type used in the Black Sea for anchovy, were introduced into the fleet. Some boats (2-4) also immigrated to this region from the Black Sea at times of potentially higher catch rates.

4.3.2 Fishing effort of the fleet

Effort statistics in Mediterranean are generally lacking (Gulland, 1979; Levi, 1990) but there may be ways of overcoming this situation. Here, regional experience on scientific fishery investigations will be important and helpful.

Based on the experience since 1980 in the region, the mean HP of the boats can be estimated as follows:

All boats in the 1-9 HP range, utilize small engines commonly used in agriculture and produced as 9 HP units. Boats of 10-19 HP utilize engines of different types with a mean power of 15 HP. In the 20-49 HP class, engines of 45 HP are common. The 50-99 HP range boats are mainly powered by engines of 75 HP and the remaining relatively large boats with engines of 150 HP. Using this information and data given in Table 5, the mean effort of the fleet can be calculated.

Although all types of boats are included in the above estimation of the fishing effort of the fleet, more specific data are provided in Appendix 1 on the effort spent by smaller boats.

For an overall approach, the use of the HP units of smaller boats seems to be reasonable, since these boats catch benthic and pelagic fish either by operating suitable passive nets (such as entangling and gill nets), or small bottom trawling nets for shrimp fishing.

4.4 Catch Per Unit Effort and Species Composition

Although the most recent statistical data are not available, the catch data of the earlier years will give some indication of the annual yields of the Turkish fleet operating in the Mediterranean territorial waters. The data are presented in Table 6.

Annual yields presented in Table 6 cannot reflect every time the real catch (total fish catch) as mentioned in the introduction. For example, the catches of 1976 and 1977 would be approximately twice as large as those in Table 6. Using possible economic incomes of the vessels, this fact was already stressed by the IMS (1979). Therefore, it is to be assumed that the yield statistics published officially may reflect at best the catches of the larger vessels (trawlers and seiners) and to some extent the artisanal catches. Some portion of the catches with stationary nets and lines may not be totally covered in the yield statistics. What error may be inherent to the data cannot be discriminated here but it is possible to make experience-based adjustments in order to obtain workable (i.e., preliminary) results. Therefore, in the following the adjusted database will be used for further approximation and evaluation.

Looking at the yield statistics a considerable jump in the yield figures in the mid-1970s may be detected. This was most predominant in 1976 and 1977. The reason for this considerable increase in total fish catch can be sought in the sardine fishery. The sardine fishery in the northeastern Mediterranean came into regular operation after 1979/80, but it is suggested that this began earlier. Nonetheless, the yield increase is remarkable. Conversations with the fishermen indicate that their catches of sardines amounted approximately to 2-3 t/day. This is a significant figure which may have caused the apparent increase in yield.

4.4.1 Catch and catch per unit effort

Measuring the effort in the form of total horsepower of all boats (Table 7) and utilizing the yield figures provided in Table 6, a rough index of the total effort in HP units and of catch rate as catch per unit HP of the fleet may be obtained (Table 8).

4.4.2 Application of the Schaefer model

The model developed by Schaefer (1954, 1957) for the estimation of maximum sustainable yield (MSY) is usually applied to single species catch and effort data. The model describes the growth rate dP/dt of a given stock of a species with biomass P (in weight units).

Considering the high number of fish species in the eastern Mediterranean, it seems to be more reliable to extend Schaefer's model to the multispecies situation by assuming that the equation describes changes in the total biomass of all species combined. This approach has been applied to various stocks, for example by Brown et al. (1976) to Georges Bank; by Halliday and Doubleday (1976) to the Scottish shelf; by Brander (1977) to the Irish Sea stocks, etc.

Based on this idea, the MSYs is calculated from the data of Tables 5, 6 and 8. The data are processed in two different ways: first without any adjustment and not taking into consideration changes in catch (yield) and effort in the mid-1970s (Table 9), and second, with and without adjustments of the total annual catches (Table 10).

As can be seen in Table 9, reliable results cannot be obtained from the data, and there is no correlation between the data pairs (catch and effort). The same situation is also valid for the data-set with adjusted yield values for the period 1968-87 (Table 6). If the data-set is divided into two parts, separated at the time of sudden yield increase, and adjusted yield values are utilized, the results given in Table 10 and Figures 7 and 8 are obtained.

A reasonable estimate of the overall MSY of the Turkish Mediterranean fishery seems to be around 11 000 t for the case of best correlation (Table 10 and Figure 8). The MSY calculated for the years 1968-77 does not reflect the present fishery situation, and is only calculated for the sake of completeness.

4.4.3 Catch per species

Statistical data on the catch per species basis are also collected by DIE but their reliability is very questionable. Therefore it is preferable to use monthly catch data obtained in the field through project work carried out between 1980 and 1984.

The main catch of the trawl fishery in Mersin and Iskenderun bays is shown in Tables 11 and 12.

Economically important and locally marketed species in both regions are: Saurida undosquamis, Mullus barbatus, Upeneus moluccensis, Solea solea, Pagellus erythrinus, Merluccius merluccius, Penaeus sp.(mostly P. kerathurus and japonicus) and Sepia officinalis. Organisms like Callinectes sp., Portunus sp., and Squilla sp., may have a potential for marketing but are still not utilized in the region. Similarly Chondrichthyes and Leiognathus may also have marketing potential but at present these are also not marketed in the region.

4.4.4 Catch per unit effort estimates of small fishing boats

For the passive gears, the time the net is in the water does not seem to be a good indicator of the effort since the success of the catch is also determined by the length of the net. Another reason is that commercial fishermen produce sound waves in the water by hitting the boat keel, and operate the net successively so as to increase the catch by increasing the effort. In any case, it is assumed that the length of the net will also determine the success of this kind of fishing operation and the effort figures can therefore be given in catch per unit time per unit length of net.

For the determination of the catch and effort of small commercial fishing boats, data from 8 of 95 commercial boats located in Mersin and the IMS boat were used. One is forced to assume that all other boats would have comparable fishing equipment. Data collected from these 9 boats are given in Table 19.

In considering these data, it would not be incorrect to assume that the net sizes and the number of hooks on a line are optimized with respect to the size of the boats. Therefore, their statistical means reflect the characteristics of the small boats operating along the Turkish Mediterranean coast. The application of these average characteristics to the period 1981-84 (when the experiments were conducted), yields the fishing effort estimates given in Table 20.

For the investigation period, the catch per unit effort of the smaller boats is estimated to be approximately 0.07 g fish/hook/h and 0.7 g fish/m/h.

The catches of 9 small boats in the size range 1-9 HP are summarized in Table 21. The main species caught in the Mersin Bay are Mugil, Lithognathus, Pomatomus and Epinephelus (Table 22).

4.5 Population Parameters

The determination of population parameters including the parameters of the growth constitute the fundamentals of the stock assessment studies. There is considerable interest in these data and there are several recent contributions dealing with this subject (Larrañeta, 1964: coast of Castellon, Spain; Rijavec and Zupanovic, 1965: in the Middle Adriatic; Girardin, 1978: around the Balearic Islands and Gulf of Lions; Andoloro and Giarrita, 1985: in the Sicilian Channel; Korbu and Vrantzas, 1988: in the Gulf of Saronikos, Greece; Livadas, 1989 a, b, c: in the waters of southern Cyprus, etc.) but almost no data are available from the northeastern Mediterranean. One of the oldest available estimates of the population parameters is given by Akyuz (1957) for the total mortality (Z) of Mullus barbatus in Iskenderun Bay.

Using the ageing method, recent estimates of Z (Table 13) and growth parameters of three fish species in Mersin Bay, are given by Bingel (1981) and summarized in Table 14. No historical data on growth parameters of fishes could not be found except for Akyuz (1957).

From data collected in the above mentioned project work, additional growth parameters were calculated by Bingel et al. (1984) using a modified form of the length-frequency distribution method of Pauly and David (1980) and the results are summarized in Table 15. Tables 14 and 15 indicate the difference between the parameters of Saurida undosquamis and Mullus barbatus, probably due to the different methods used.

Approximate methods were applied to calculate mortality parameters. Utilizing the Gulland (1969) formula, the suggestion of Bingel (1985) is used for assessing total mortalities. The natural mortality is then calculated first by applying the empirical formula of Pauly (1980), and second, that of Ursin (1967). For the latter calculations, the length-weight relationship is given in Table 16.

Calculated mortality parameters using the data in Tables 15 and 16 are given in Table 17. Natural mortality (M) calculated on the basis of the Pauly (1981) method resulted in much higher (M) values. Therefore these are not included in Table 17.

4.6 Application of the Yield per Recruit Model

Since the growth parameters are available, the yield equation first derived by Beverton and Holt (1957) can be dealt with. Their original formula incorporates the number of recruits which is not easy to determine. Therefore the simplified version (Jones, 1957) of this equation is solved as the yield per recruit (Y/R) for different demersal fish species.

Arnoglossus laterna: With E = 0.602 the fishery is not at the optimal level but is rather close to it. Since the exploitation rate is higher than the optimum, it could be argued that the stocks of this fish are slightly overfished. A slight decrease in fishing intensity and an increase in l are advisable (Figure 9).

Bothus podas: This flatfish mostly occur close to Erdemli (ca 10 n.mi to the west). The exploitation rate with E = 0.916 is much above the optimum, and hence the stock is highly overfished. A decrease of (F) to the half the existing level will yield an approximation to the optimal yield/range. Even then the stock would be suspected to be slightly overfished (Figure 10).

Citharus linguatula: Similar to that of the previous individuals, this species is also overfished. Its exploitation rate with E = 0.756 is close to that of A. laterna. Both A. laterna and C. linguatula are small flatfishes. A slight decrease in fishing intensity would be advisable (Figure 11).

Leiognathus klunzingeri: This small-sized fish has an exploitation rate of E = 0.722 and, surprisingly, is overfished. This is probably due to the body shape which causes a higher retention rate in the cod-end (Figure 12).

Mullus barbatus: With an exploitation rate of E = 0.799 the stocks of this fish are heavily overfished. An increase of l = 8 cm to = 14 cm accompanied by a reduction of the (F) to nearly half the existing level, will be advisable for a recovery of the stocks and an approximation to the optimal Y/R criterion (Figure 13).

Pagellus erythrinus: The stocks are highly overfished (E = 0.911). As for M. barbatus, a reduction of (F) to half the existing level and an increase of l = 7 cm to about l = 14 cm, will result in a fishery around the optimal level (Figure 14).

Saurida undosquamis: This Indo-Pacific originated fish with a spindle body shape seems to be less vulnerable to the existing mesh size. Its exploitation rate at E = 0.566 could be assumed as optimal with l around 13 cm (Figure 15).

Solea solea: The exploitation rate of this fish is E = 0.918 and hence far from the optimum. A decrease of (F) to about half the existing level will create an (E) close to optimum. The cumulative mean length of 13 cm is reached by 49% of the catch and 62% by 14 cm. An increase of l to about 23 cm by a decrease of (F) to half the existing level will be necessary to reach optimal utilization (Figure 16).

Upeneus moluccensis: 37-60% of this Indo-Pacific originated fish caught have mean lengths of 9-10 cm respectively. With an lc of about 6 cm and an E = 0.891 the stocks of this fish are highly overexploited. An increase of l to about 12 cm and halving of (F) will create a fishery close to the optimal Y/R (Figure 17).

4.7 Trawlable Biomass

Using the swept-area method, estimates of trawlable biomass were made from data covering the period 1983-84. Biomasses are estimated for the coastal region between Anamur and Iskenderun. The coverage includes a depth range of 0-100 m (Figure 6). The estimated figures are given in Table 18.

To have an idea of the productivity of the coastal zone east of Anamur, the biomass figures were converted also into kg/ha units. In the shelf area, production is found to range between 15 and 49 kg/ha, with a mean of 29 kg/ha within the depths of 0-100 m (Table 14). This is nearly twice that given by Ben-Tuvia (1983) for the continental shelf area of the whole Mediterranean.

This difference may due to higher productivity of the study region. This part of the Mediterranean Sea is greatly enriched by riverine input and hence its productivity is relatively high (Koblentz-Mishke et al., 1970; Parson and Takahashi, 1977; Ketchum, 1967 and Venric, 1972).

4.8 Conclusions and Summary of Results

The percentage distribution of the species representing the main catch of the trawl fishery in the coastal region of Mersin and Iskenderun Bays is given in Tables 11 and 12. It can be seen that the number of species is around 15. This is rather high compared to other temperate areas (e.g., Black Sea). However, the real number of species encountered in the trawl catches is much higher. Bingel (1987) gives for four successive tows of one-hour duration, the minimum and maximum number of species as 18 and 38 respectively. The mean of this is 31 species and hence as underlined by Levi (1990, p. 41) ..."(generally, most Italian and Mediterranean fisheries with the exception of that in the Adriatic Sea) have features of both typical tropical fisheries (e.g., large numbers of species, of fishermen and landing sites, lack of historical data series and difficulties in biostatistical data collection and interpretation) and of the industrial fisheries of so-called developed countries."... This is also the case for the Turkish Mediterranean coast.

Given the above, an attempt is made to critically evaluate the fisheries statistical data for 1968-87 and estimate the catch per unit effort of the Turkish Mediterranean fishing fleet. This is found to be between 0.28 and 1.04 t/HP in the years 1968-87 (Table 8).

Utilizing catch and effort data, it is possible to assess the MSY of the total catch of the Turkish fishery. It is found that the Turkish catch and effort data can be divided into two significant periods, i.e., data for 1968-77 and 1977-87. The catch and effort relation seems to have changed in 1977-78. Application of the Schaefer (1954,

1957) model to the data revealed for the first period about 3 000 t and for the second 11 200 t of maximum sustainable yield (biomass). This can be explained through the introduction of the seine fishery on sardine to the region during that period.

The total biomass above the 100 m isobath is estimated for the coastal strip between Anamur in the west and Iskenderun in the east for 1983 and 1984. It is established that the minimum biomass is about 14 000 t. Since these figures cover almost half of the coastline, it is better to work with the production values. It is claimed that this difference may be due to the relatively higher productivity of the area under study.

To assess the trawlable biomass, the catchability of the net is assumed to be 100% (equal to a catchability coefficient of q = 1). These biomass figures and calculated production values (kg/ha) therefore reflect the minimum amount.

While the main catch in the Bay of Iskenderun was composed of Saurida, Leiognathus, Callinectes and Portunus and Chondrichthyes, it was Saurida, Chondrichthyes, Mullus and Callinectes and Portunus in the Bay of Mersin.

An application of the yield per recruit (Y/R) model to the stocks whose population parameters were estimated revealed that except for Saurida undosquamis all other stocks (A. laterna, B. podas, C. linguatula, L. klunzingeri, M. barbatus, P. erythrinus, S. solea and U. moluccensis) were overfished. A halving of F and an increase of l would give the same yield per recruit (with less effort).

4.9 Suggestions for Research and Management

Bingel (1987) found a logarithmic relationship between the biomass (catch kg/h) and the number of boats working on fishing grounds (Figure. 18)

$$(y = a + b \ln x \; ; \; a = 59.707 \; ; \; b = -10.844 \; ; \; r = 0.7074)$$

This result and the findings of Clark (1979, 1981) imply that the monitoring of trawlable biomass would probably give a fair idea about the yield possibilities of the fleet and the region. This would be worth further study. Additionally, the swept-area method can lead to an estimate of the potential yield. Therefore, it is suggested that the biomass estimation studies applying the swept-area method be continued and enlarged to cover the continental shelf area along the Turkish Mediterranean coast.

It is also appropriate that the stock model of Beverton and Holt (1957) also be taken into consideration. The construction of yield-isopleth diagrams will then be helpful for taking the necessary management measures such as regulating the allowed mesh-size in parallel to and/or instead of seasonal fishing activity bans.

In addition, because of the known difficulties of statistical data collection in scattered, small sites such as on the Turkish Mediterranean coast, it is recommended that additional effort be made to collect data for further assessment of catch and effort.

Stock assessment investigations should probably consider the multispecies situation in the cases where single species assessments do not give proper objectives.

The larger part of the Turkish Mediterranean coast consists of hard bottom. It is therefore advisable to introduce trawl nets suitable for hard bottom. Eventual introduction of hard bottom trawl nets should be followed by the limitation of vessel sizes and numbers, to prevent depletion of the stocks.

Since better and more suitable data on stocks are not readily available, the regulation through closed seasons should be continued.

In summary, it must stressed that investigations on fish stocks be understood as a monitoring programme of the aquatic resources. Therefore, an unlimited continuation of such studies should be an appropriate decision on the part of planners and resource managers.

To overcome such problems indicated above, a mixture of cooperative stimuli, proper action of the countries bordering the Mediterranean Sea and extended critical research activities of the organizations of these countries seem to be obligatory and should be established. Much effort and support should be given to case study contributions (e.g., Sanders and Morgan, 1989) to deal with local and overall fishery problems as exemplified by Levi (1990).

In accordance with the suggestions above, the IMS-METU has conducted projects in which field data were obtained on coastal fisheries in the eastern part of the Turkish Mediterranean coast, where the shelf area is relatively wide and the commercial activity is high (Figure 6). An evaluation of data to be collected (similar to the previous endeavour of the IMS-METU) and estimates of biological parameters which were recommended as a necessary database by Charbonnier and Caddy (1986) should be continued.

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Table 1. Types of Pollutants Entering the Northern Levantine Basin

Pollutant	D	I	A	R	AT	SA
Total discharge	+	+	+	+	-	+
Organic matter:						
BOD	+	+	+	+	-	+
COD	+	+	+	+	-	+
Nutrients:						
Phosphorus	+	+	+	+	-	-
Nitrogen	+	+	+	+	+	-
Specific organic matter:						
Detergents	+	+	-	+	-	+
Phenols	+	+	-	+	-	-
Mineral oil	+	+	-	+	-	+
Metals:	+	+	+	+	+	+
Mercury	+	+	+	+	+	+
Cadmium	+	+	+	+	+	+
Lead	+	+	+	+	+	+
Chromium	+	+	+	+	+	+
Zinc	+	+	+	+	+	+
Manganese	+	+	+	+	+	+
Copper	+	+	+	+	+	+
Iron	+	+	+	+	+	+
Suspended matter:	+	+	+	+	+	+
Pesticides:						
Organochlorine	-	-	-	-	-	-
Radioactivity	?	?	?	?	?	?

D: Domestic, I:Industrial, A:Agricultural, R:Rivers,
AT:Atmospheric, SA:Shipping Activities

Table 2. Estimated Annual Pollution Loads in the Levantine Basin and the Aegean (All figures in t/year or percenges)

Sea area		Aegean		N.LEVANTINE		S.LEVANTINE		TOTAL
Pollutant		t/y	%	t/y	%	t/y	%	t/y
1. Volume:		47	11	25	6	18	4	428
2. Organic matter:								
BOD	* 10^3	330	10	140	4	150	5	3 250
COD	* 10^3	950	11	550	5	300	3	8 600
3. Nutrients:								
Phosphour	* 10^3	33	9	19	5	20	6	358
Nitrogen	* 10^3	90	9	51	5	40	4	1 042
4. Specific organics:								
Detergent	* 10^3	6.0	10	2.7	5	3.5	6	59.7
Phenola	* 10^3	0.9	7	0.2	2	0.4	3	12.4
Mineral Oil	* 10^3	4	4	27	23	13	11	115
5. Metals:								
Mercury		14	11	7	5	7	5	130
Lead		440	9	180	4	230	5	4 820
Chromium		290	11	150	5	260	9	2 760
Zinc		2500	10	1100	4	1200	5	24 700
6. Suspended matter:								
TSS	* 10^6	(-)	-	(-)	-	(-)	-	(-)
7. Pesticides:								
Organochlorines		7.4	8	6.7	7	9.0	10	90
8. Radioactivity								
Tritium	Ci/a	-	0	-	0	-	0	2 480
Other radionuclides	Ci/a	-	0	-	0	-	0	38

Legend: :(-) insufficient data base for estimate

Table 3. Estimated Loads of Pollutants in the Northern Levantine Basin

Pollutant	Pollution Source	originating in coastal zone: Domestic t/y	Domestic %	Industrial t/y	Industrial %	agricul. t/y	agricul. %	carried by rivers t/y	rivers %	TOTAL %
1. Volume:										
Total disch. $10^6 m^3$/yr		19	~0	25	~0	-		25000	100	25 000
2. Organic matter:										
BOD	* 10^3	6.2	5	7.8	6	195	14	100	75	133
COD	* 10^3	13	3	20	4	300	58	180	35	513
3. Nutrients:										
Phosphorus	* 10^3	0.24	1	0.05	~0	5.6	29	13	69	19
Nitrogen	* 10^3	1.9	4	0.5	1	12.2	24	36	71	51
4. Specific organic matter										
Detergents	* 10^3	0.19	0.007	-	-	-	-	2.5	93	2.7
Phenols	* 10^3	-	-	0.15	68	-		0.7	32	0.22
Mineral Oil	* 10^3	-		27.0	0.1	-	-	(-)		27.0
5. Metals:										
Mercury		0.01	~0	0.05	1	-	-	7	99	7.1
Lead		2.2	1	8.0	4	-	-	170	95	180
Chromium		2.2	2	3.0	2	-	-	140	96	145
Zinc		23	2	24	2	-	-	1100	96	1.150
6. Suspended matter:										
TSS	* 10^3	9.3		2.7		9.4		(-)		(-)
7. Pesticides:										
Organochlorines		-		-	-	-		6.7		100
8. Radioactivity:										
Tritium	Ci/a	-	-	-	-	-	-	(-)		
Other radionuc	Ci/a	-	-	-	-	(-)		(-)		-

Table 4. Estimated Atmospheric Inputs of Heavy Metals to the Northern Levantine Basin

Metal	Load (t/a)	Reference
Mercury	5	Chester et al. (1983) Models
Cadmium	15	UNEP (1984)
Lead	1 720	Chester et al. (1983) Models
Zinc	1 163	UNEP (1984)
Copper	105	UNEP (1984)

Table 5. Number of Fishing boats by Horse Power (HP), (DIE, 1968; 1971; 1974; 1979; 1981 a, b; 1982; 1984; 1985; 1986 a,b; 1988; 1989)

Years	Number of boats by HP						Total number
	0	1-9	10-19	20-49	50-99	100+	
1968	56	202	38	23	24	24	367
1969	62	209	55	26	26	30	408
1970	100	167	63	16	10	16	381
1971	65	213	62	37	13	18	408
1972	62	208	51	33	9	17	380
1973	12	210	92	12	23	27	376
1974	14	211	86	12	27	29	379
1975	19	278	109	10	19	26	461
1976	9	235	189	2	22	48	505
1977	28	440	170	36	28	26	728
1978	18	383	169	25	14	57	666
1979	9	319	144	10	24	51	557
1980	71	430	139	30	32	60	762
1981	-	664	174	1	11	51	901
1982	6	577	150	12	34	65	844
1983	1	541	241	32	13	59	887
1984	-	565	250	24	28	46	913
1985	2	516	208	66	30	66	888
1986	9	503	218	74	38	64	906
1987	30	408	257	176	36	53	960

Table 6 Yields for the years 1968-1987 (DIE., 1968; 1971; 1974; 1979; 1981 a, b; 1982; 1984; 1985; 1986 a,b; 1988;1989)

Years	Yield (Tons)
1967	3420
1968	7135
1969	4315
1970	3335
1971	3220
1972	2803
1973	2312
1974	2911
1975	3004
1976	3225
1977	4183
1978	9806
1979	7500
1980	7876
1981	12117
1982	10613
1983	14763
1984	10507
1985	10693
1986	14061
1987	13074

Table 7. Mean Horse Power of the fleet. Data utilized are from Table 6

Years	Total HP of the size ranges					Total
	9	15	45	75	150	HP
	1-9	10-19	20-49	50-99	100+	of the fleet
1968	1818	570	1035	1800	3600	8823
1969	1881	825	1170	1950	4500	10326
1970	1503	900	720	750	2400	6273
1971	1917	930	1665	975	2700	8187
1972	1872	765	1485	675	2550	7347
1973	1890	1380	540	1725	4050	9585
1974	1899	1290	540	2025	4350	10104
1975	2502	1635	450	1425	3900	9912
1976	2115	2835	90	1650	7200	13890
1977	2700	2550	1620	2100	3900	12870
1978	3447	2535	1125	1050	8550	16707
1979	2871	2160	450	1800	7650	14931
1980	3870	2085	450	1500	7500	15405
1981	5976	2610	450	825	7650	17511
1982	5183	2250	540	2550	9750	20283
1983	4869	3615	1440	975	8850	19749
1984	5085	3750	1080	2100	6900	18915
1985	4770	3450	2970	2550	9900	23640
1986	4527	3270	3330	2850	9600	23577
1987	4320	3855	4500	2700	9000	24375

Table 8. Catch and Catch per Unit Effort of the Fleet Asterisk (*) indicates assumed data base

Years	Yield (Tons)	Total HP of the fleet (Effort)	Catch/HP (Tons)
1968	4500*	6835	1.04
1969	4315	8070	0.53
1970	3335	4850	0.69
1971	3220	6055	0.53
1972	2803	5345	0.52
1973	3000*	7695	0.30
1974	2911	8150	0.36
1975	3004	7820	0.38
1976	3225	11470	0.28
1977	4183	10870	0.38
1978	9806	18397	0.53
1979	10000*	14931*	0.50*
1980	12000*	20095	0.39
1981	12117	18846	0.64
1982	10613	21783	0.49
1983	13000*	22159	0.67
1984	10507	21415	0.49
1985	10693	24964	0.43
1986	10000*	23577*	0.60*
1987	10000*	24375*	0.54*

Table 9. MSY Application to the Original Data

	Original (whole) data set of the years 1968-1987	Original data set of the years 1968-1977	Original data set of the years 1978-1987
Slope (b)	= -1.96×10^{-6}	-4.87×10^{-5}	-3.27×10^{-5}
Incp (a)	= 0.5355	0.8491	0.5814
Corr. (r)	= 9.11E-02	-0.5359	-0.1375
fopt	= 136615.3	8287.2	88980.3
MSY	= 36578.7	36578.7	25867.2

Table 10. MSY Application with Yield Adjusted (Modified) Catch Figures.

	Yield adjusted (whole) data set of the years 1968-1987	Original data set of the years 1968-1977	Yield adjusted data set of the years 1978-1987
Slope (b)	= -3.267×10^{-6}	-4.869×10^{-5}	-2.3688×10^{-5}
Incp (a)	= 0.5814	-4.869×10^{-5}	1.0289
Corr. (r)	= -0.1375	-0.7788	-0.8846
fopt	= 88980.3	8719.3	21714.7
MSY	= 25867.2	3701.8	11171.9

Table 11. Main Catch in Mersin Bay Covering the Coastal Area Between Goksu River Delta and Karatas Cape (calculated from catch/h data; May 1980-November 1982; depth range between 0-50m)

Organisms	%
Saurida undosquamis	17.95
Chondrichthyes	15.99
Mullus barbatus	9.04
Callinectes & Portunus	7.54
Leiognathus klunzingeri	7.16
Trigla sp. (often *T. lucerna*)	6.32
Squilla sp.(mostly *S. desmaresti*)	4.07
Arnoglossus sp. (mainly *A. laterna*)	3.70
Upeneus moluccensis	3.11
Penaeus sp. (mostly *P. kerathurus & japonicus*)	3.02
Solea solea	2.52
Sepia officinalis	2.17
Others	17.41
Sum	100.00

Table 15. Growth Parameters of some Fish in the Eastern Mediterranean Coast of Turkey

Species	Region and Parameter					
	Mersin bay			Iskenderun bay		
	L (cm)	K	t	L (cm)	K	t
A. laterna	15	0.82125	-0.24	15	0.82125	-0.24
B. podas	16	0.76650	-0.25	-	-	-
C. linguatula	27	0.62050	-0.27	-	-	-
L.klunzingeri	11	2.04400	-0.99	11	1.32617	-0.18
M. barbatus	24.4	0.71581	-0.45	-	-	-
P. erythrinus	30	0.59700	-0.27	30	0.63875	-0.25
S.undosquamis	42	0.41975	-0.36	42	0.41975	-0.36
S. solea	43	0.45260	-0.33	-	-	-
S. aurata	26	0.84600	-0.20	26	0.86500	-0.20
U. moluccensis	25.6	0.62100	-0.27	25.6	0.62100	-0.27

Table 16. Length-weight Relatiõn of Some Fish in the Eastern Mediterranean Coast of Turkey

Species	$w = a\ l^{b}$	Corr. coeff.
A. laterna	$w = 0.000015\ l^{2.9746}$	0.8422
B. podas	$w = 0.010046\ l^{1.6405}$	0.5116
C. linguatula	$w = 0.000003\ l^{3.1376}$	0.7785
L. klunzingeri	$w = 0.000017\ l^{2.9286}$	0.8320
M. barbatus	$w = 0.000011\ l^{3.0018}$	0.9351
P. erythrinus	$w = 0.000722\ l^{2.2026}$	0.7993
S. undosquamis	$w = 0.000140\ l^{2.4518}$	0.9648
S. solea	$w = 0.000013\ l^{2.8792}$	0.9019
U. moluccensis	$w = 0.000014\ l^{2.9768}$	0.9105

Table 17. Mortality Parameters of Some Fish in Mersin and Iskenderun Bays

Species	Mersin bay Z_1	Z_2	M	Iskenderun bay Z_1	Z_2	M
A. laterna	0.958	1.327	0.456	1.402	1.781	0.456
B. podas	1.281	1.634	0.122	-	-	-
C.linguatula	0.969	1.253	0.271	-	-	-
L.klunzingeri	1.608	2.492	0.570	1.116	1.693	0.570
M. barbatus	1.225	1.555	0.280	-	-	-
P. erythrinus	1.769	2.051	0.170	1.610	1.909	0.170
S.undosquamis	0.772	0.967	0.378	0.975	1.172	0.378
S. solea	1.185	1.399	0.106	-	-	
U.moluccensis	1.237	1.630	0.159	1.790	2.192	0.159

Table 18. Trawlable Biomass between Anamur and Iskenderun for a Depth Range of 0-100m (Production kg/ha is given in parenthesis)

Region	Autumn 1983 tons	Spring 1984 tons	Autumn 1984 tons
Iskenderun bay	4274 (21.3)	2943 (15.0)	3854 (20.9)
Mersin bay	6960 (26.7)	6440 (25.0)	7043 (27.4)
Goksu-Anamur	2900 (32.7)	4626 (49.0)	3889 (43.7)
Totals	14134	14009	14785

Table 19. Effort of Some Small Boats in Size Class 1-19 Horse Power
(Data obtained from a second net set are given in brackets)

Boats number	Time period of the year covered (months)	Mean working time per day (h)	Mesh size and length of nets used (mm and m)		Number of hooks per line
I	Feb., March	12	28 (34)	190 (120)	450
II	Feb., March	12	28 (34)	170 (120)	500
III	Feb., March	12	28	300	1700
IV	Feb., March	12	28	200	-
V	Feb., March	12	28	170	400
VI	Feb., March	12	28	180	750
VII	Feb., March	12	28	200	750
VIII	Feb., March	12	25	180	-
IX	May 81.Oct. 81	17	28 (34)	150 (125)	-
Mean		12.6		234	506

Table 20. Assumed Effort of Small Boats in 1-19 Horse Power Range for the Years 1981-1984

Years	Number of boats	Mean number of hooks (hooks/h)	Mean length of gill and entangling nets (m/h)
1981	6936	928	429
1982	7760	1039	480
1983	7669	1027	475
1984	8585	1149	531

Table 21. Catches of Small Boats in the Size Range 1-19 Horse Power

Time period	Total working time (hours)	Gill net (kg)	Entangling net (kg)	Hooks (kg)
May 1981-October 1984	792	339.72	185.96	-
February 1982-July 1982	2 028	3 599.3		684

Table 22. Main Catch of Small Boats in the Erdemli-Mersin Region

Organisms	%
Mugil sp.	33.98
Lithognathus mormyrus	21.70
Pomatomus saltator	15.44
Epinephelus sp.	13.63
Umbrina cirrhosa	5.73
Seriola dumerili	2.54
Argyrosomus regium	1.80
Myctioperca rubra	0.88
Sarda sarda	0.43
Selar djeddaba	0.37
Diplodus sp.	0.28
Boops sp.	0.28
Lichia amia	0.22
Sparus aurata	0.17
Sardine sp.	0.11
Pagrus pagrus	0.09
Alosa sp.	0.04
Penaeus sp.	0.02
Dasyatis, Myliobatis, Rhinobatus	0.34
Others	1.95
Total	100.00

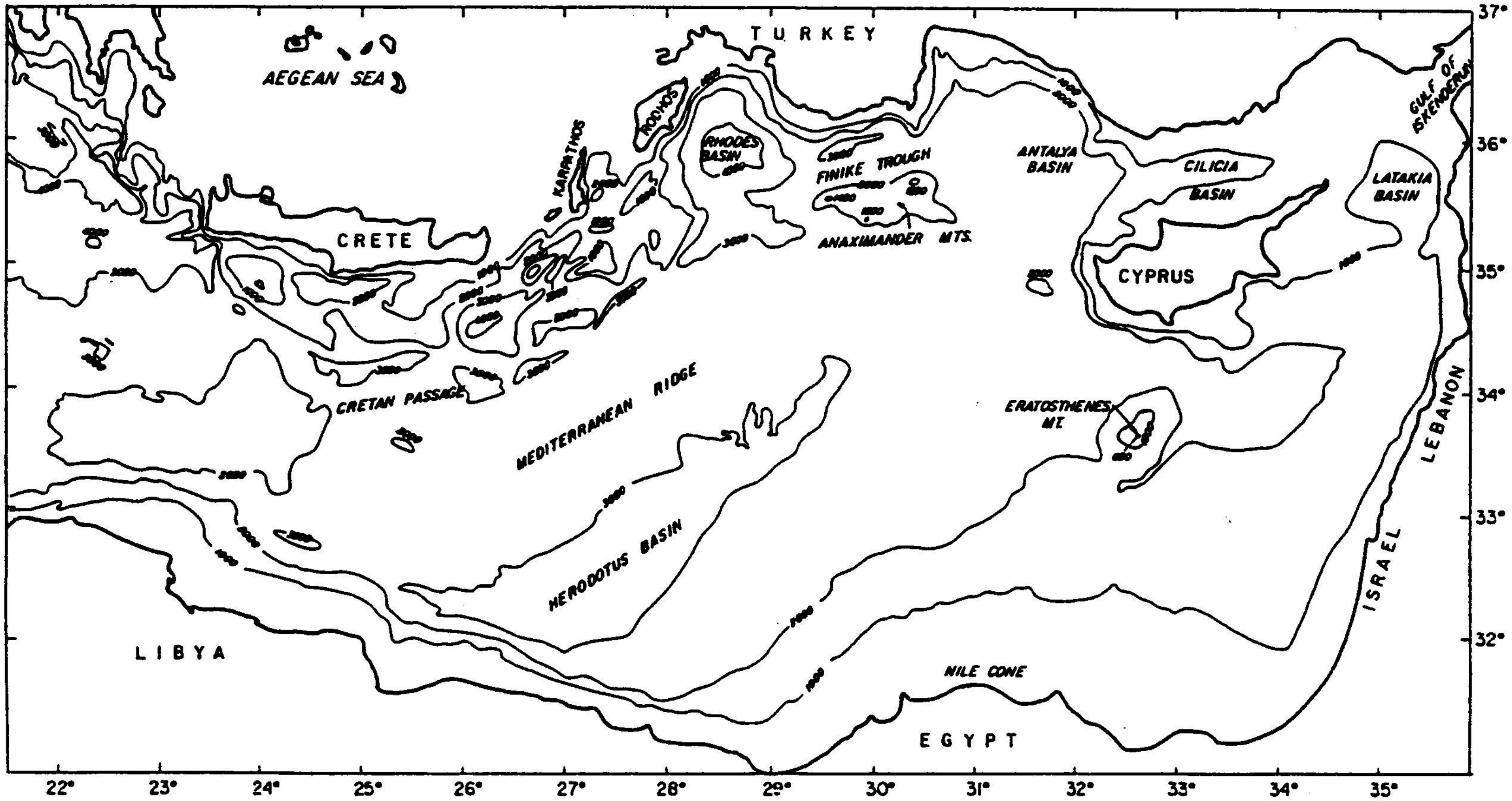

Figure 1. Location map and bottom topography of the Levantine Basin

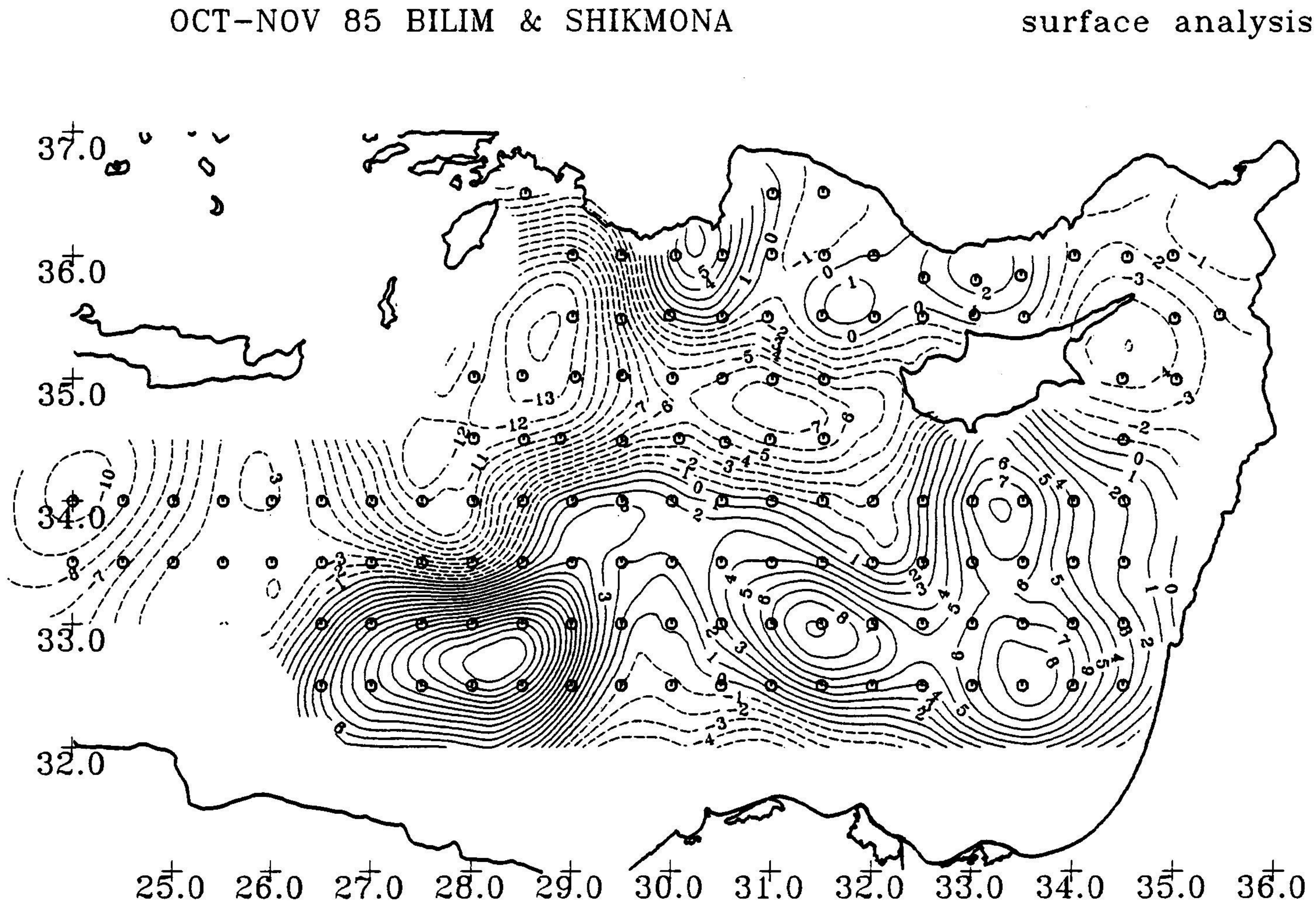

Figure 2a. Surface circulation in the Levantine Basin for October - November 1985 obtained from the POEM coordinated surveys of the RV BİLİM and RV SHIKMONA

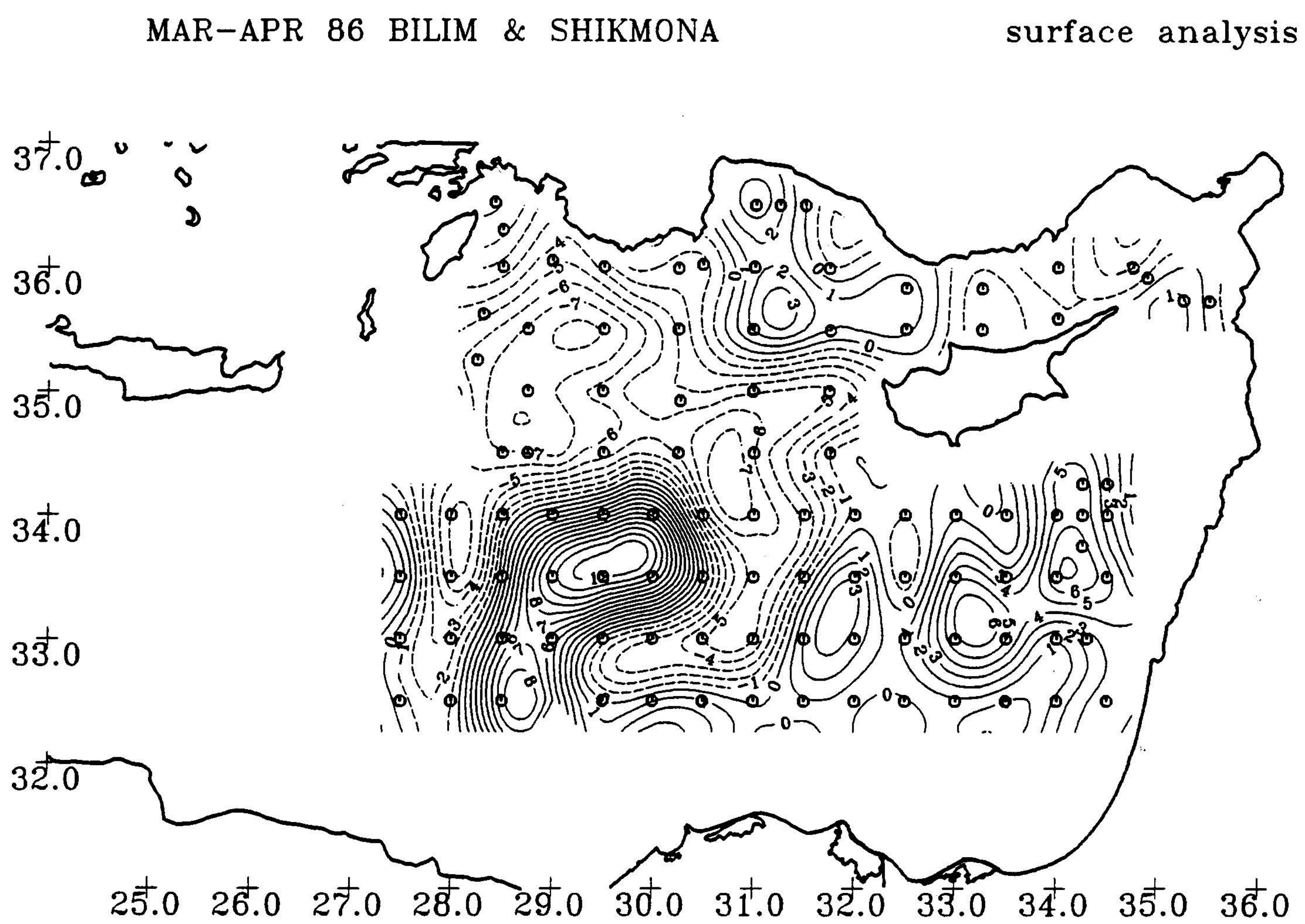

Figure 2b. Surface circulation in the Levantine Basin for March – April 1986 obtained from the POEM coordinated surveys of the RV BİLİM and RV SHIKMONA

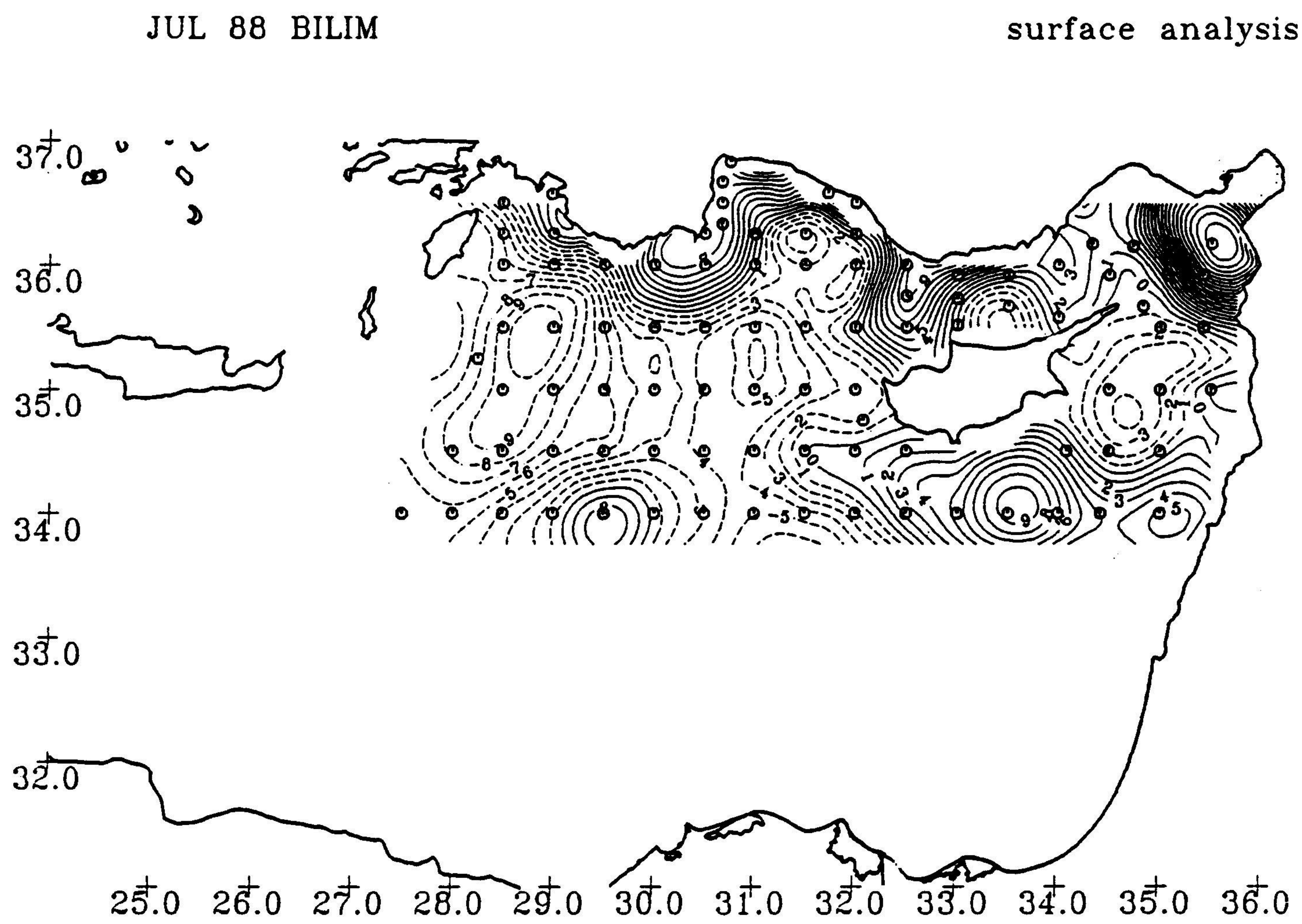

Figure 2c. Surface circulation in the northern Levantine Basin for July 1988 obtained from a survey of the RV BİLİM

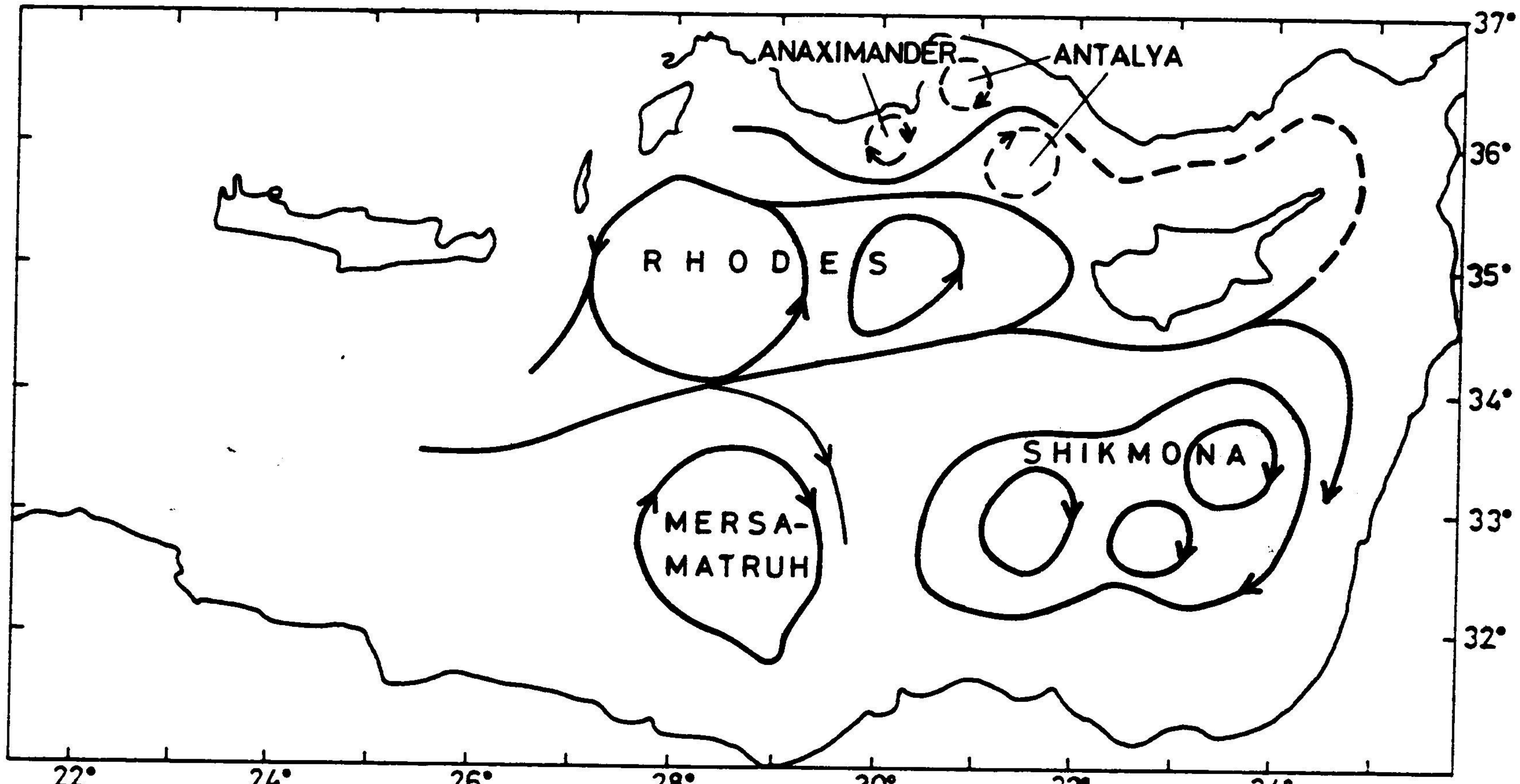

Figure 2d. A schematics of Levantine Basin surface circulation as synthesized from recent studies

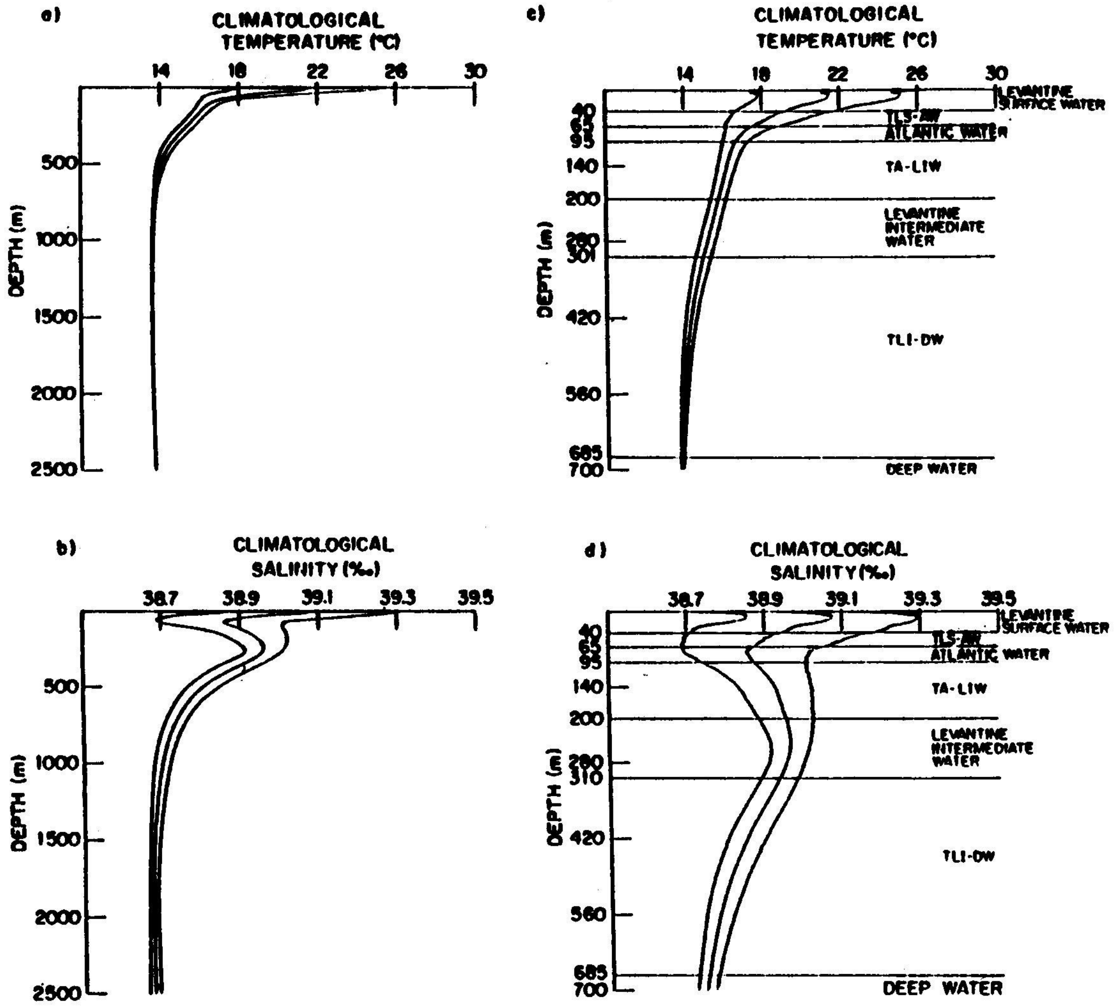

Figure 3. Climatological average temperature (a) and salinity (b) profiles and their standard deviations. (c) and (d) are the same as (a) and (b) enlarged for 0-700m to show water masses. (After Hecht, *et al.*, 1988)

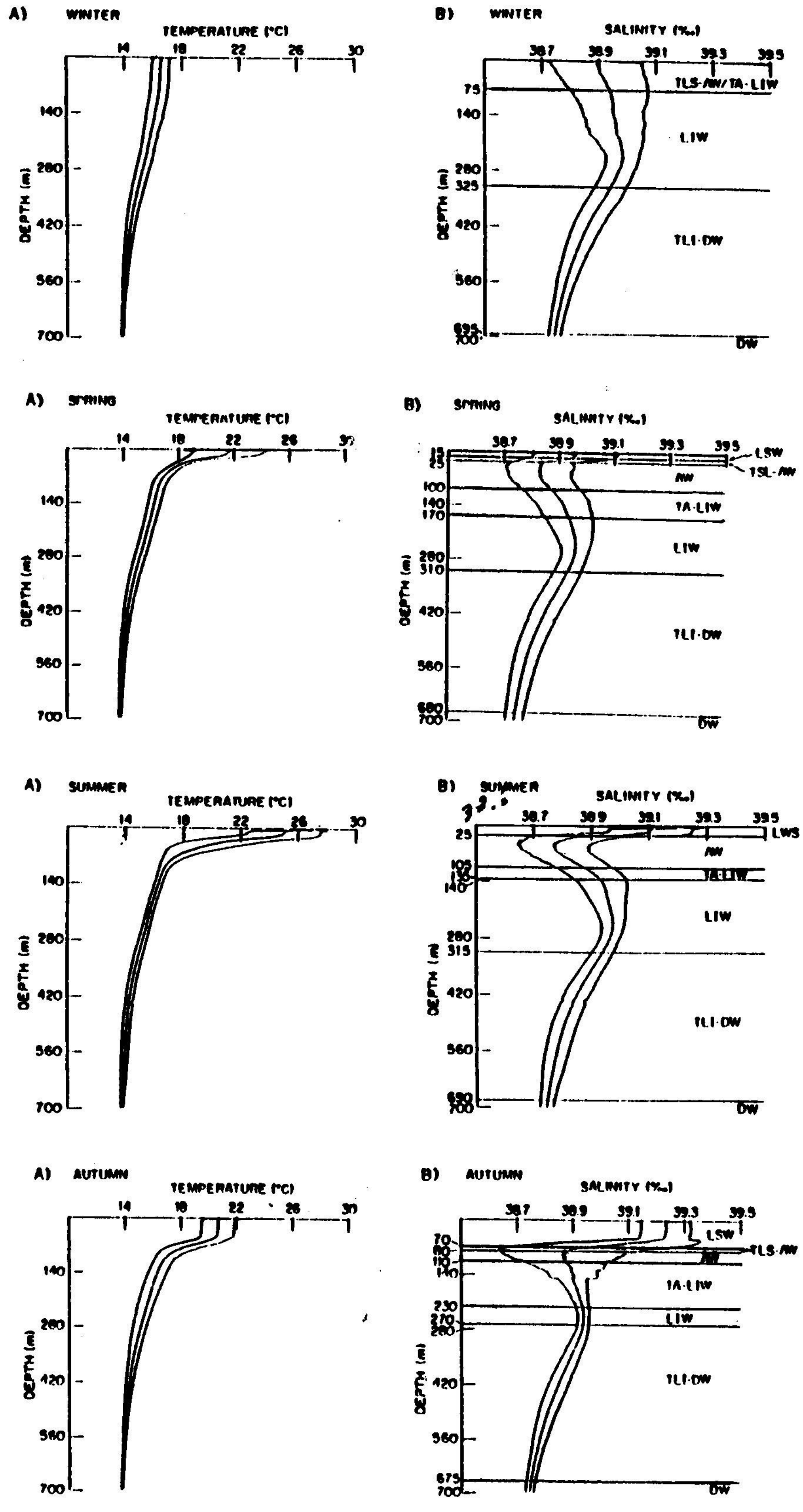

Figure 4. Climatological seasonal average temperature (a) and salinity (b) profiles and their standard deviations. Top row: winter, second row: spring, third row: summer, bottom row: autumn (After Hecht, *et al.*, 1988)

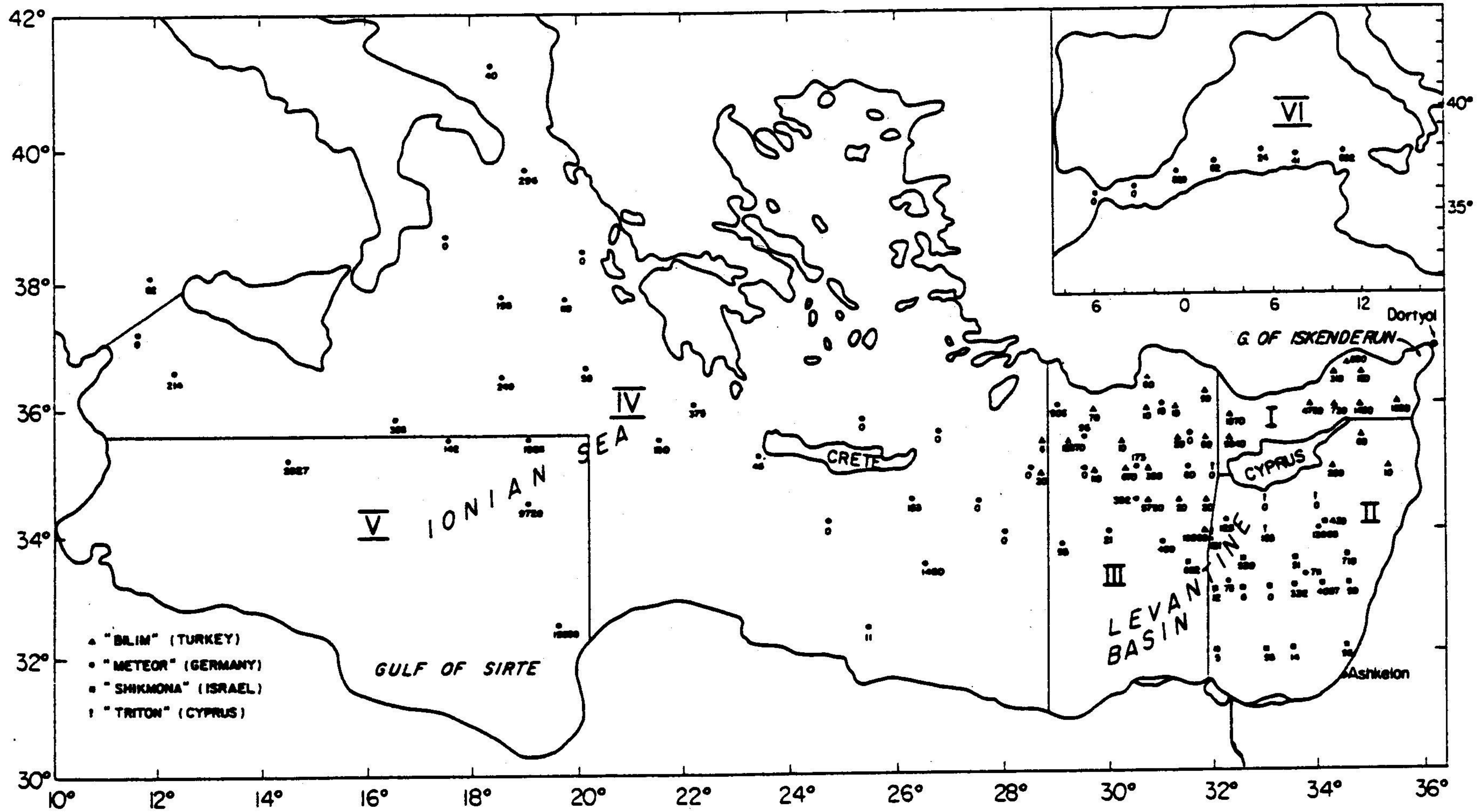

Figure 5. Pelagic tar quantities, in $\mu g\ m^{-2}$, in the Mediterranean Sea in summer 1987. (after Golik *et al.*, 1988)

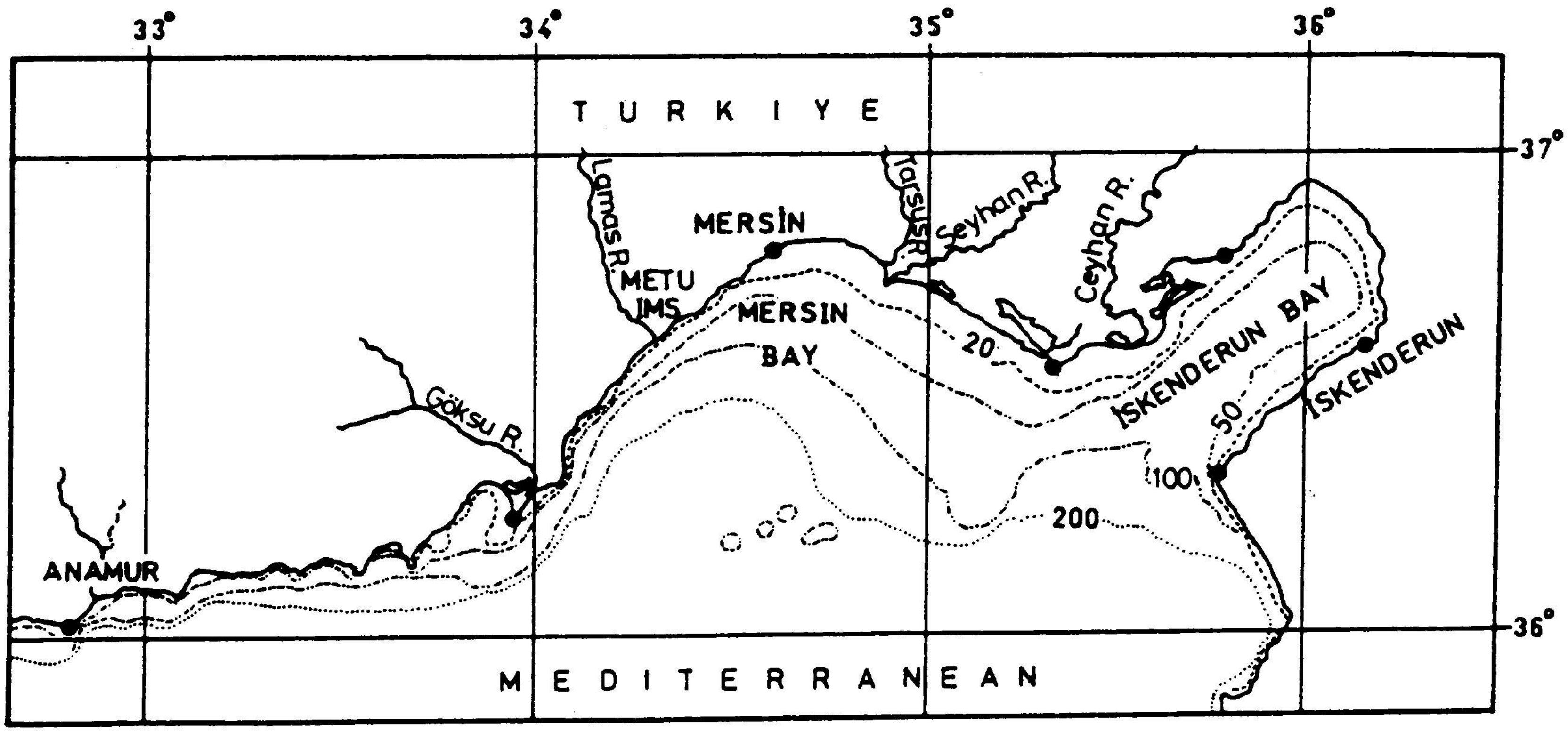

Figure 6. The fisheries study area

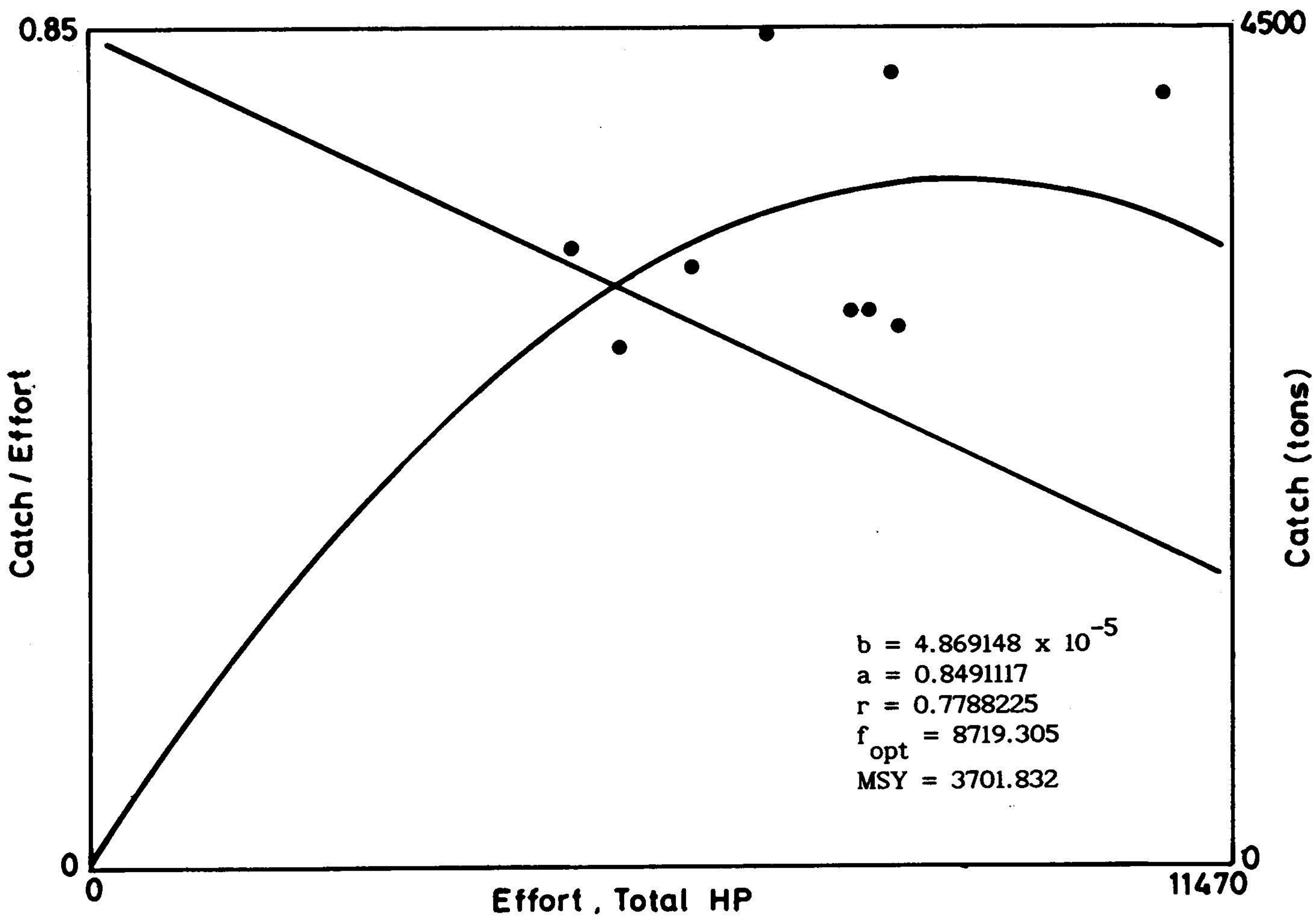

Figure 7. Maximum sustainable yield calculated using original data set of the years 1968-1977

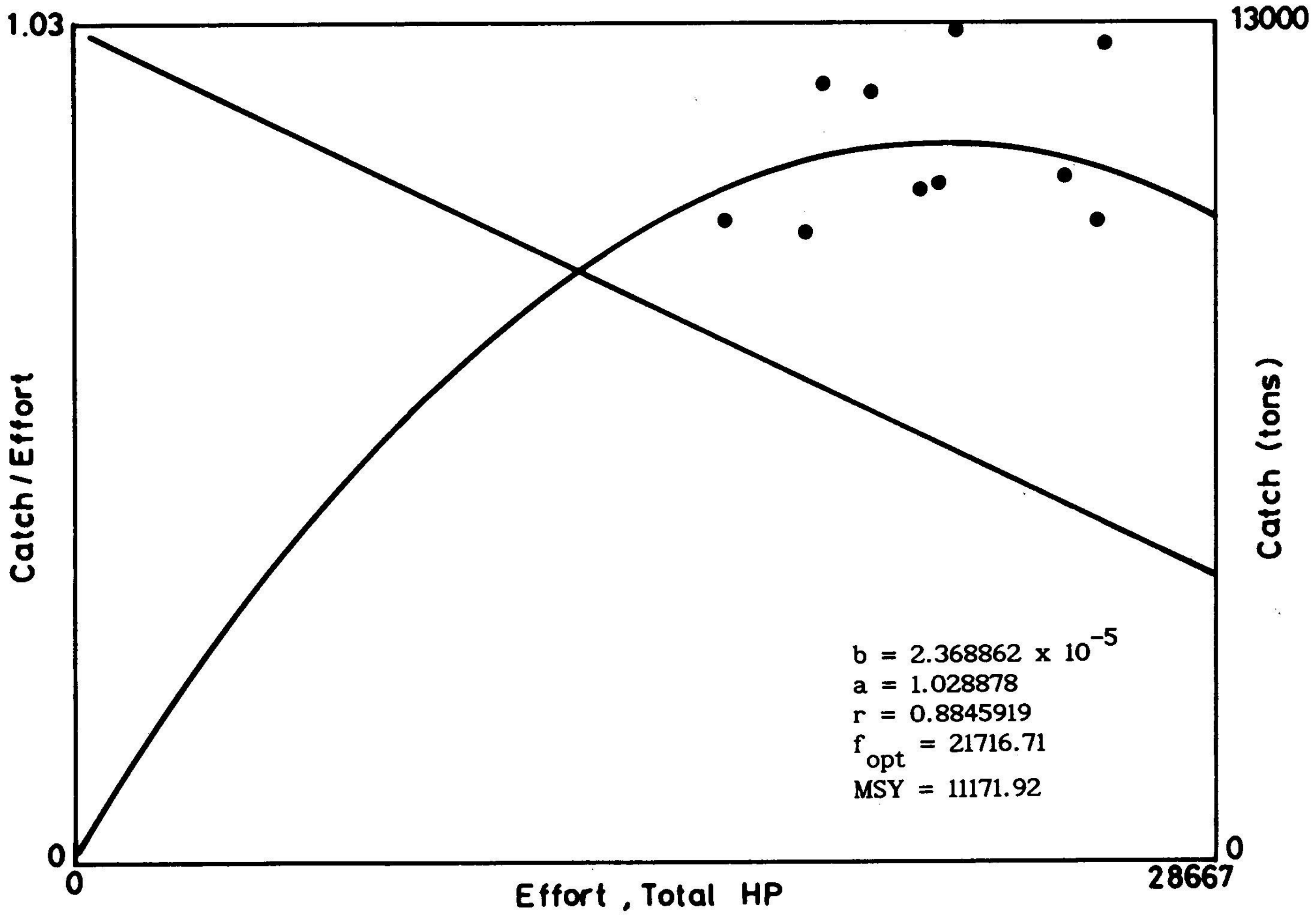

Figure 8. Yield adjusted maximum sustainable yield of the Turkish Mediterranean fishery for the years 1978-1987

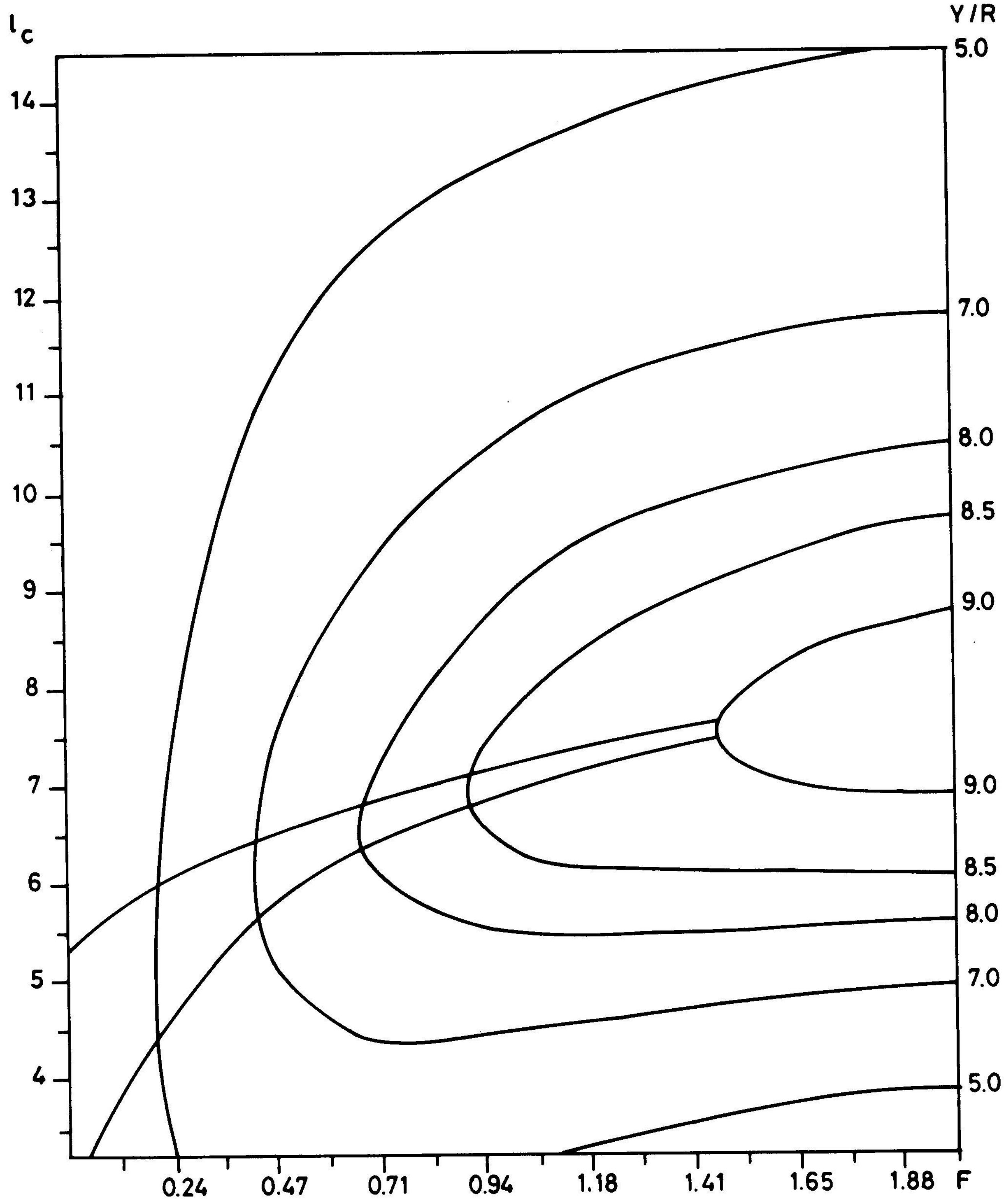

Figure 9. Yield - isopleth diagram of *Arnoglossus laterna* and the area of best fishing.

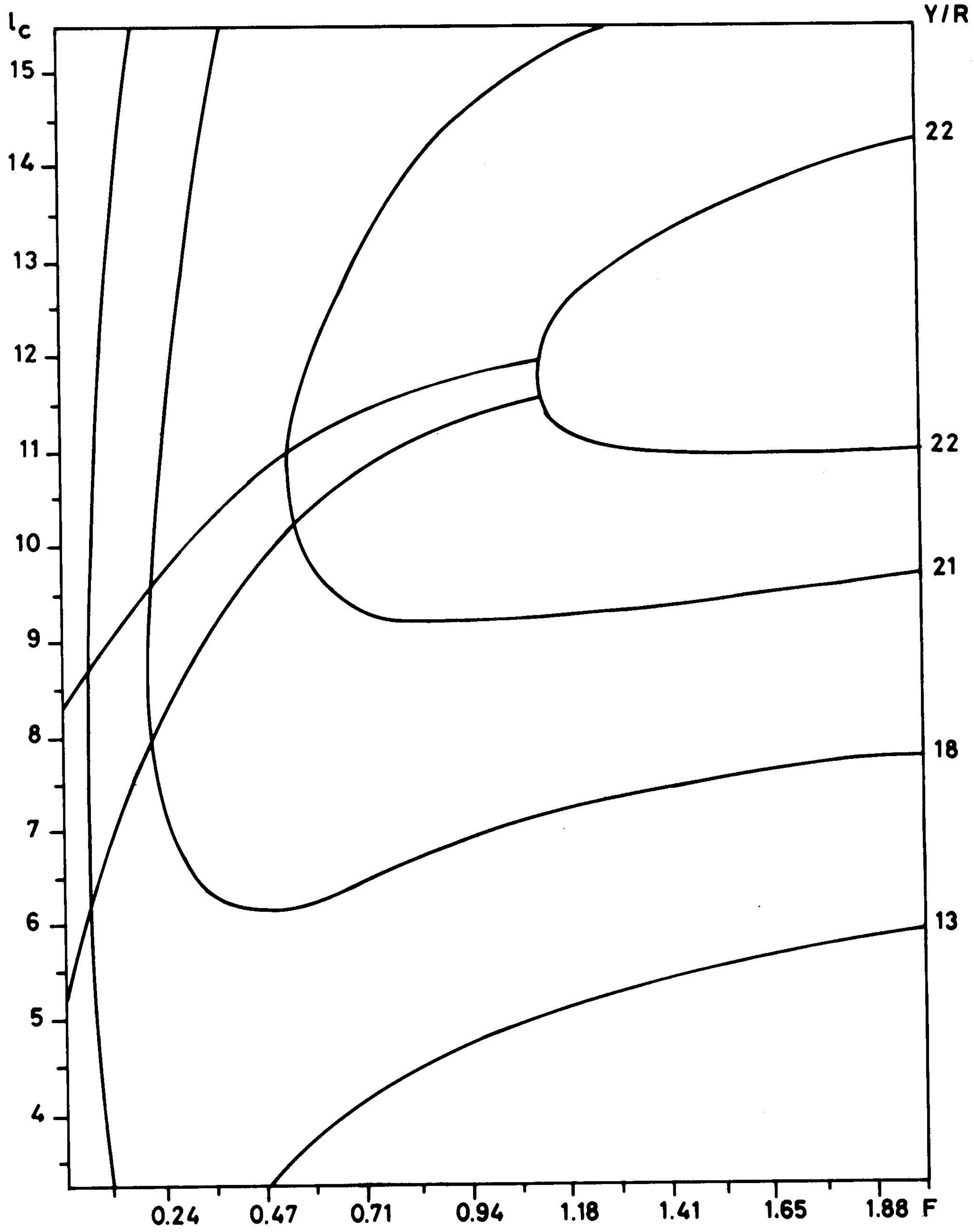

Figure 10. Yield - isopleth diagram of *Bothus podas* and the area of best fishing.

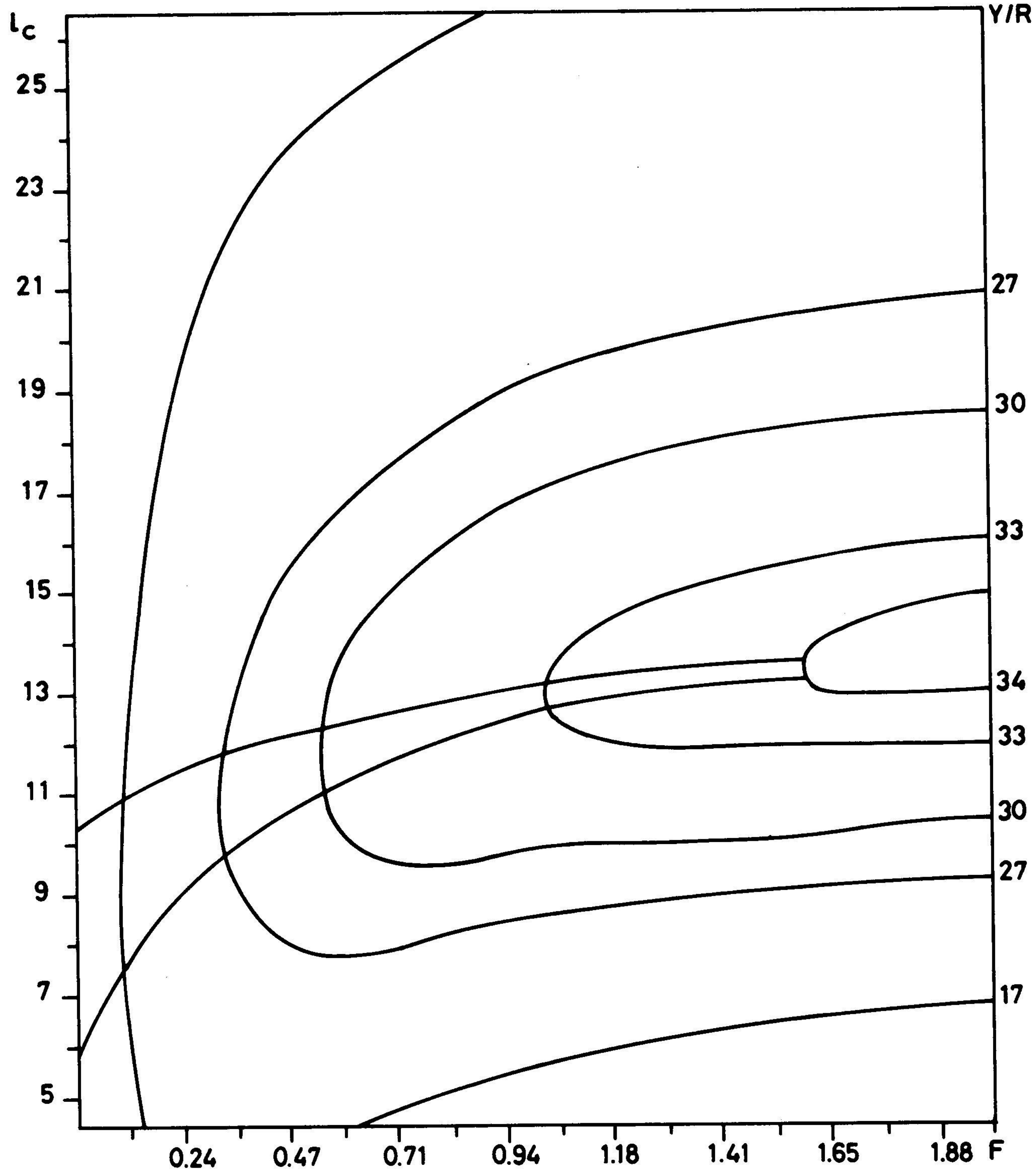

Figure 11. Yield - isopleth diagram of *Citharus linguatula* and the area of best fishing

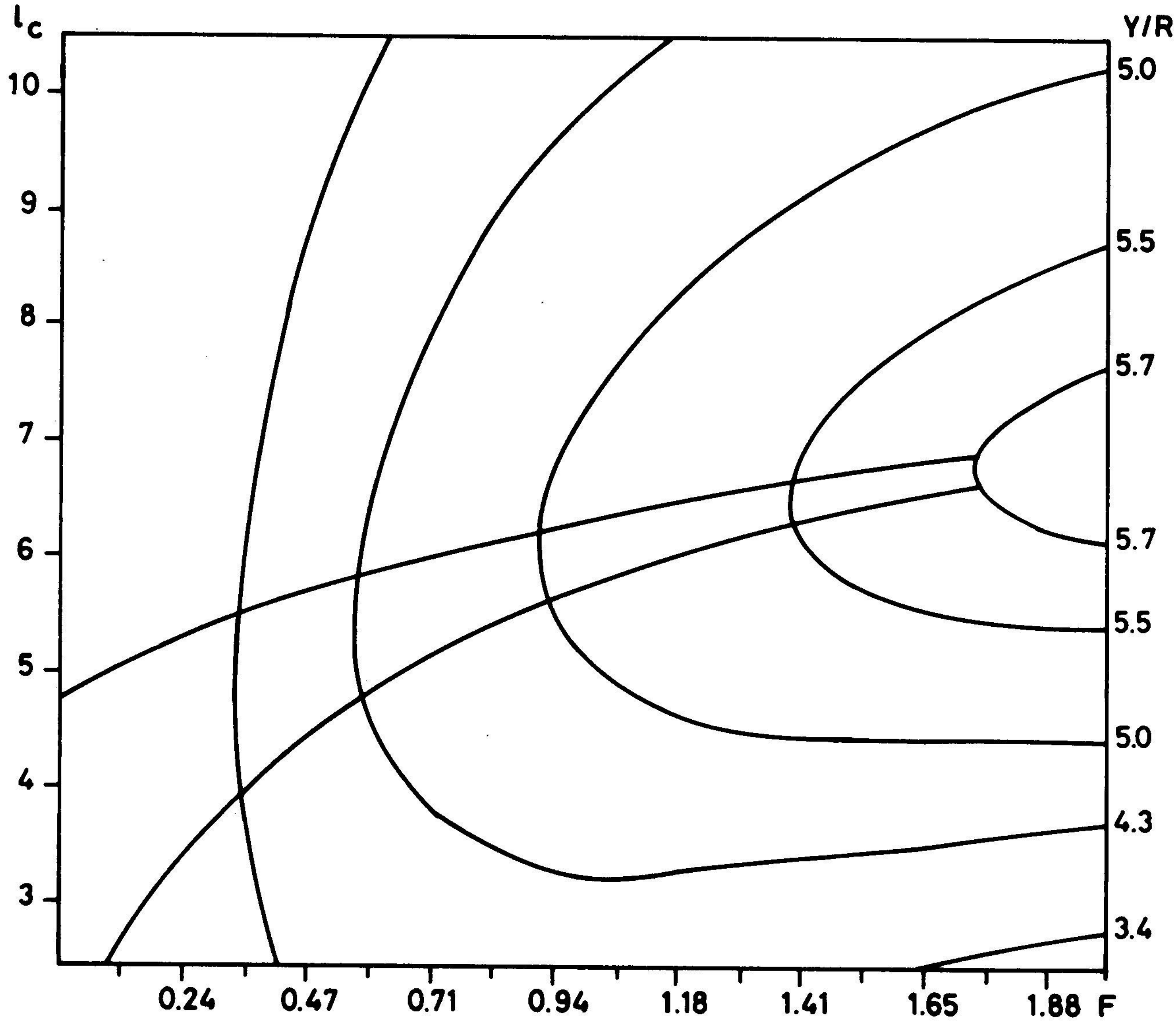

Figure 12. Yield - Isopleth diagram of *Leisguathus klunzingeri* and the area of best fishing

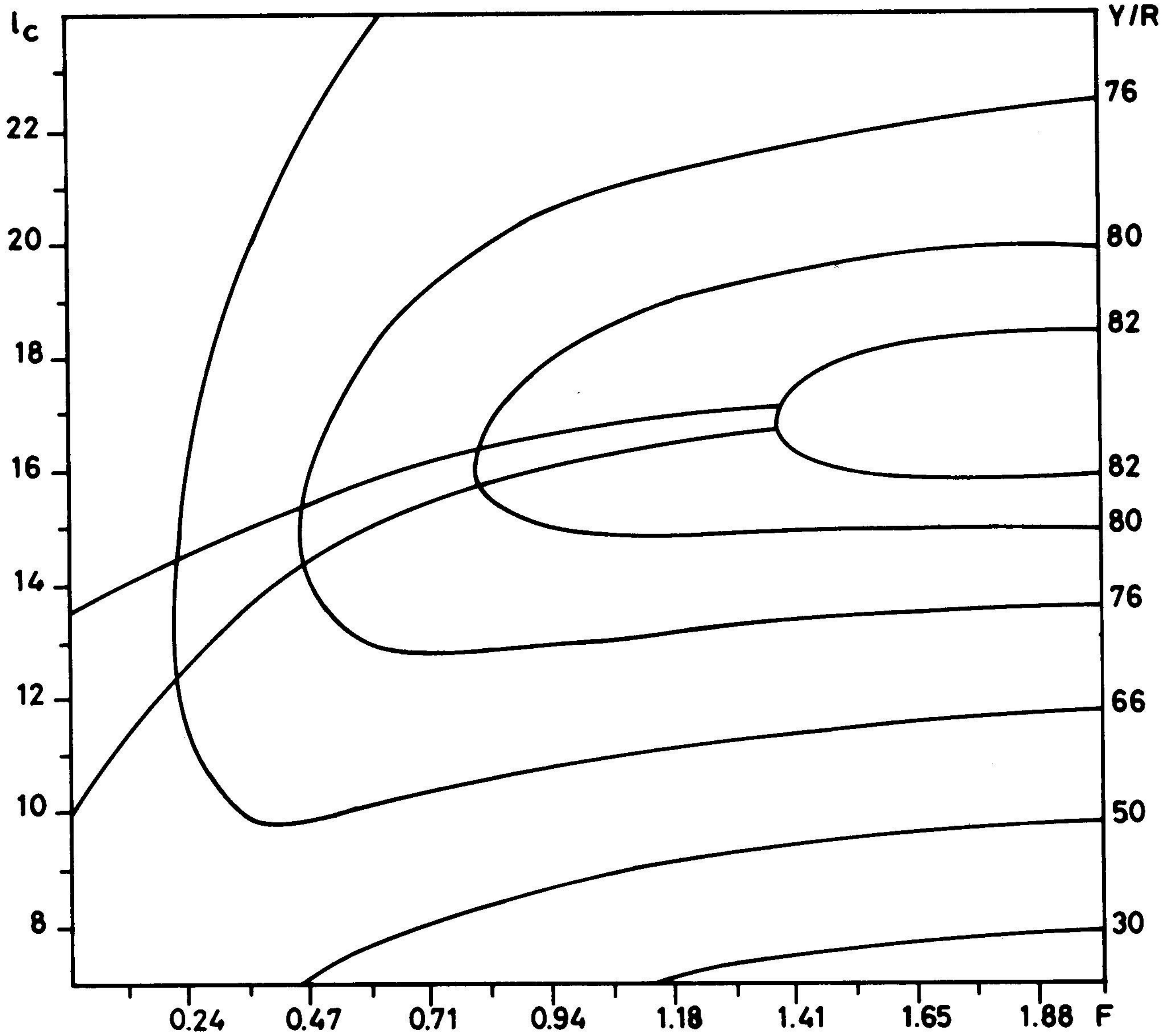

Figure 13. Yield - isopleth diagram of *Mullus barbatus* and the area of best fishing

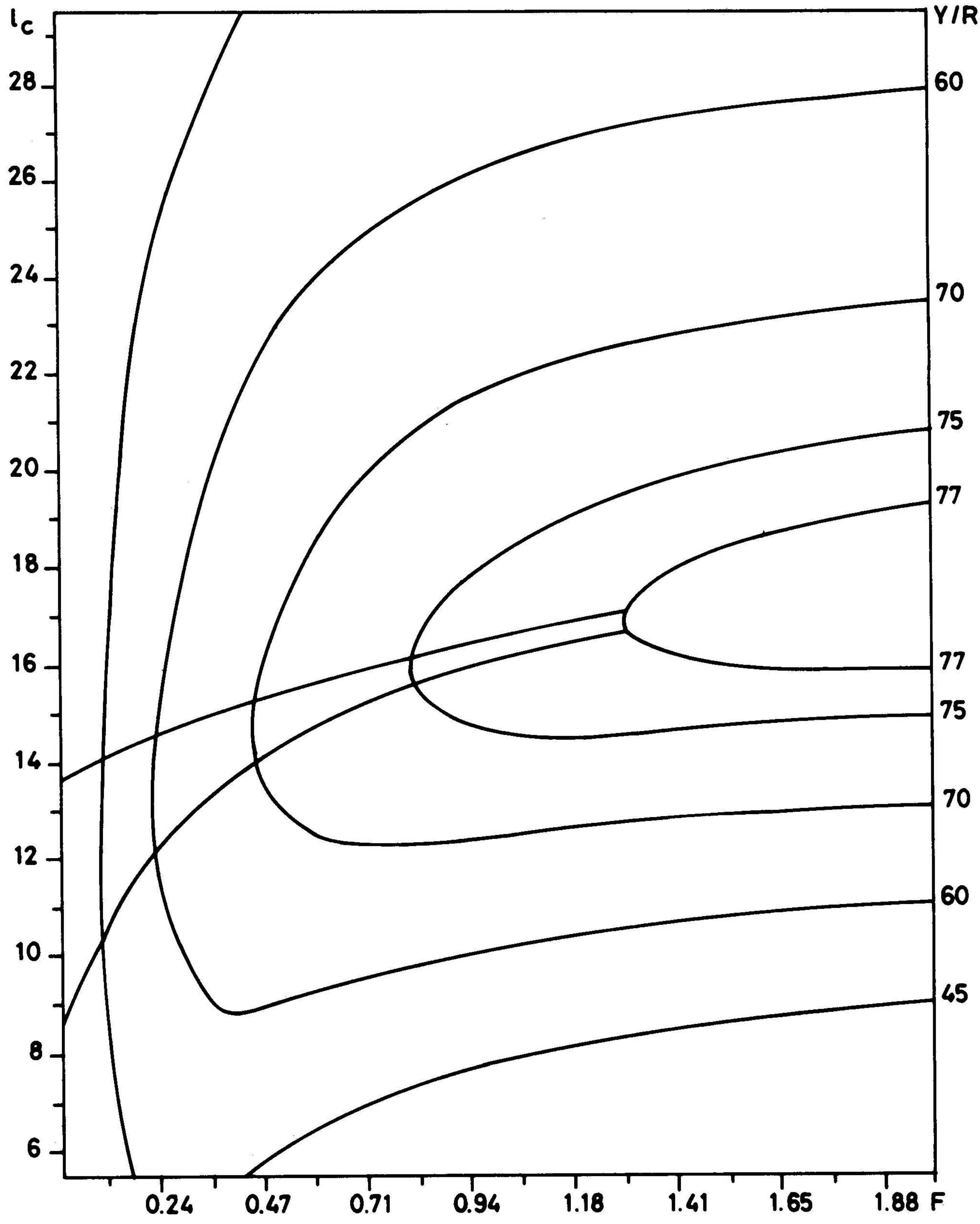

Figure 14. Yield - isopleth diagram of *Pagellus erythrinus* and the area of best fishing

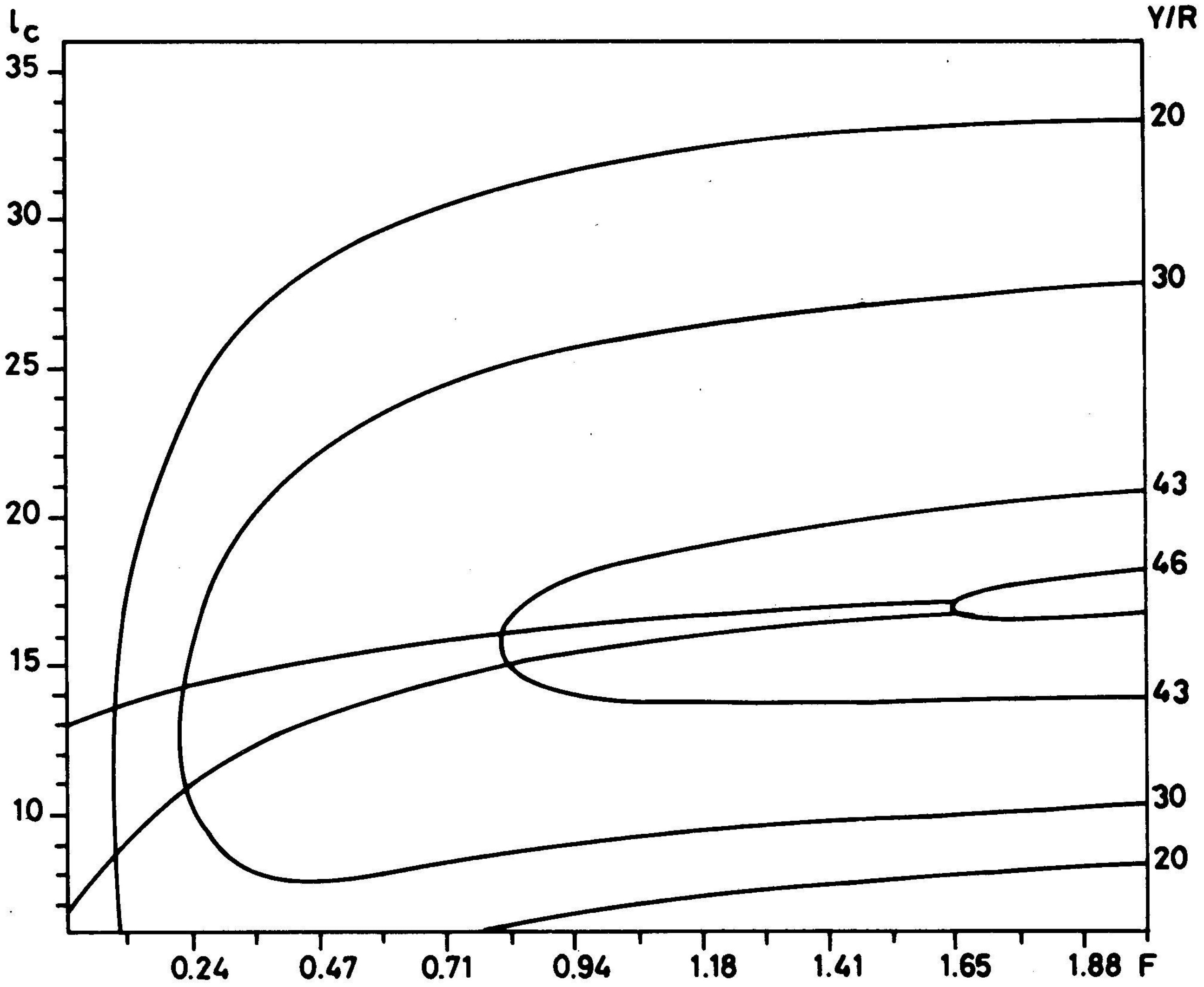

Figure 15. Yield - isopleth diagram of *Saurida undoquamis* the area of best fishing

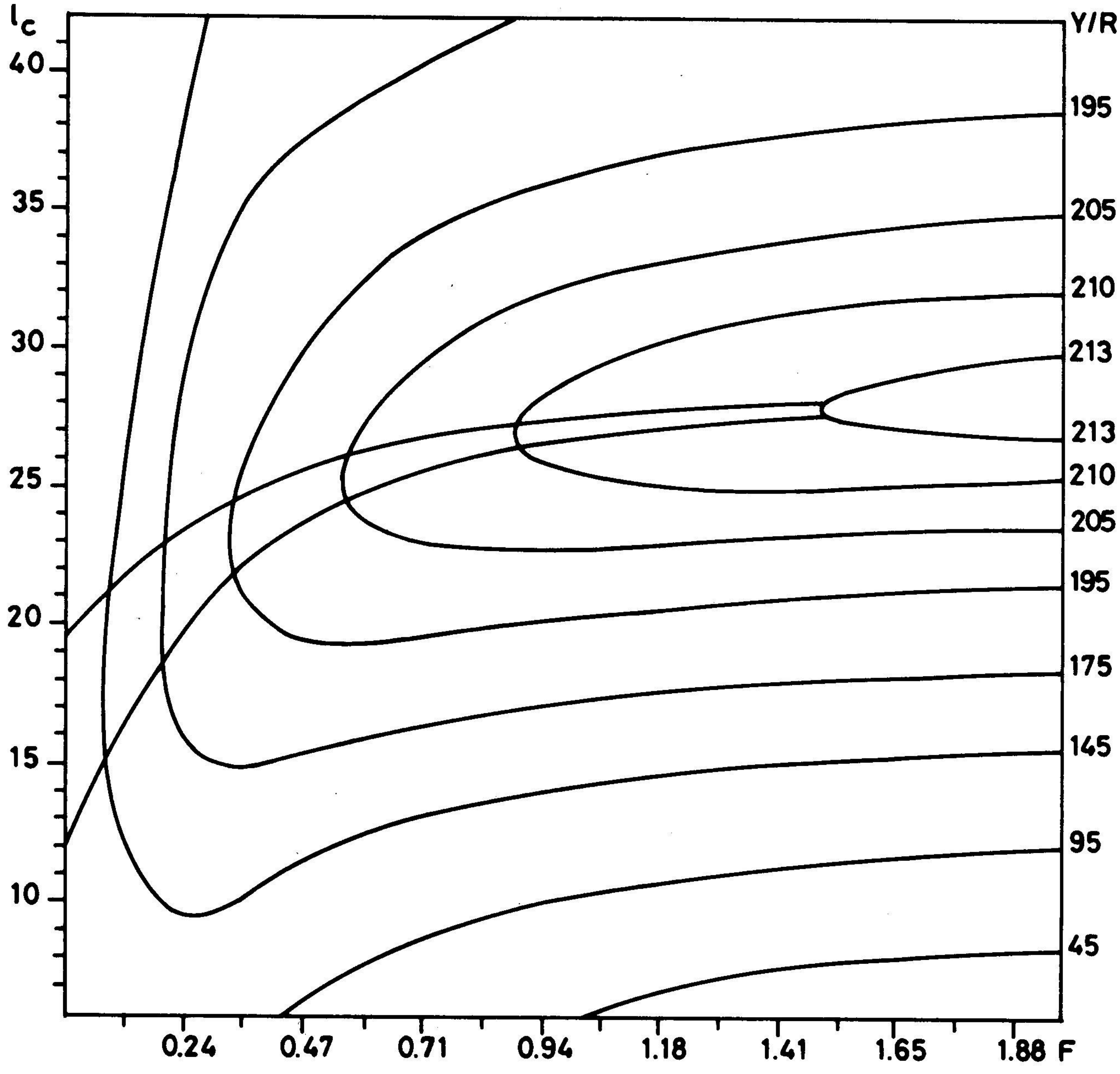

Figure 16. Yield - isopleth diagram of *Solea solea* and the area of best fishing

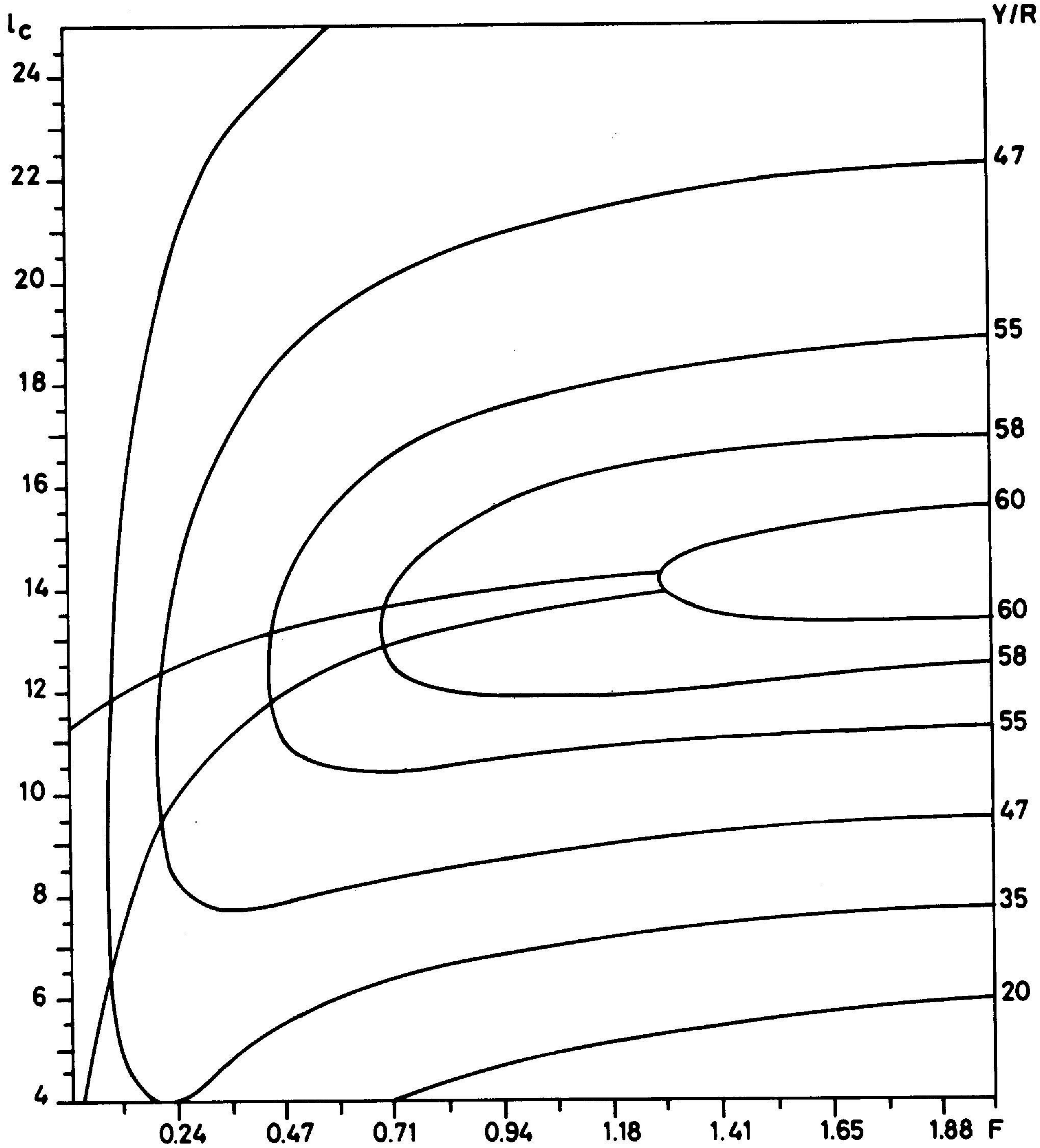

Figure 17. Yield - isopleth diagram of *Upeneus moluccensis* and the area of best fishing