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Ecological study of gas fields in the northern Adriatic

11. Ecological characteristics of the pelagic community

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On the basis of the studied material from March 1986, as well as previously obtained statistical data, new characteristics of the pelagic community have been shown. Due to their behaviour, organisms of this community were observed on a wider area as to better define the area of IVANA and IKA gas fields.

This paper brings facts on the temporal and spatial distribution of primary production, concentration of chlorophyll a, zooplankton and bacterioplankton.

The main species of small pelagic fish (sardine, sprat, anchovy) were observed bearing in mind the seasonal and spatial movement and their concentration.

The absolute abundancy of sardine stock was determined. Analyses of the catch were performed considering the agregation level of the population.

The length, isometric growth of the length and weight were studied, as well as FOULTON's condition coefficient, and the relations between the sexes of small pelagics.

11.1. INTRODUCTION

Regarding the pelagic community it is difficult to characterize a small area in the open sea, such as the IVANA and IKA gas fields, without widely considering the northern and also the entire Adriatic. The favourable circumstance is that for certain links of the pelagic community precious facts exist from the beginning of the century. This part of the Adriatic was later systematically studied by experts from the Centre for Marine Research of the Ruder Bošković Institute in Rovinj and the Marine Biological Station in Piran as well as by a number of Italian scientific institutions, in particular the Istituto di Zoologia e Anatomia comparata in Trieste. General planktonological features were observed, the primary and secondary production and the structure and distribution of the pelagic biomass in the northern Adriatic. The stock size, temporal and spatial distribution of the small pelagic fish were studied as well, particularly its migration. The knowledge about sources of pollution of this aquatorium has improved as well as ecological consequences of sea pollution on different parameters of the pelagic community.

The area is partly influenced by the waters from the south, and partly by the land inflows especially the Po River. The main part of the fresh water of this river joins the general Adriatic cyclonic circulation flowing along the Italian coast, but it also occasionally spreads towards Istria. This water, enriched with nutrients, has an impact on the distribution of species as well as their biomass. Satellite images of May 31, 1982 (NYKJAER et al., 1983) properly illustrate this situation.The extent of richer and more turbid water between the Po River delta and Istria is in correlation with the quantity of the Po River flow. According to these data the northern boundary of the clear and poorer water reaches approximately the Rovinj - Rimini profile.

According to SOURNIA (1973) the annual yield by the Po River is about 41 395 t NO_3, 806 t NO_2 , 7 994 t NH_3, 1 806 t PO_4 and 110 141 t Si. According to more recent data by MARCHETTI (VUKADIN, 1991), Italian rivers annually bring into the Adriatic 29.4 x 10^3m^3 phosphoric salts and 221.9 x 10^3m^3 nitrogen salts. As the Po River is the main source of nutrients, the biological richness of this part of the Adriatic is greatly influenced by the inflow of this river.

11.2. MATERIAL AND METHODS

Apart from the data obtained in the IVANA gas field at stations 1, 2, 3 and 4 in March 1986 (Fig. 1.2.), published data on the spatial and temporal distribution of the parametres of the pelagic community in the northern Adriatic were also used and synthesized in this paper. Samples for the study of small pelagic fish originate from the area of the IVANA gas field and the neighbouring areas: Kvarnerić and the Velebit Channel. Data on the catch refer to the western Istrian area and the northern Adriatic in general (1975/1983). Statistical data regarding fisheries were obtained from the Institute of Statistics in Zagreb. Data on daily catches per boat (purse-seier) and per species were obtained from the company whose fleet worked on this area.

Published data on heterotrophic bacteria were scarce so that the conclusions were mostly based on the data from field work at our stations (March 1986).

Most of the data regarding primary production was determined by radioactive carbon method (^{14}C) by measuring the potential photosynthetic activity in 3-hour experiments, with the addition of $NaH^{14}CO_3$ and against constant sunlight and temperature (SMODLAKA, 1985). The data from stations 1 - 4 were obtained by measuring the "in situ" production on a number of samples, taken verticallly from the surface to the compensation depth in 6-hour experiments. Results were given in mg C $m^{-3}h^{-1}$, in mg C m^{-2} day^{-1} and g C m^{-2} $year^{-1}$ (STEEMAN NIELSEN, 1952).

The phytoplankton abundance was obtained by settling samples of 25 or 50 ccm volume, preserved with 2.5% neutral formaldehyde and by counting them on an inverted microscope according to Utermöhl. The abundance wasgiven in number of cells l^{-1}.

The greatest part of the net zooplankton samples for qualitative and quantitative analyses was obtained by vertical hauls from the bottom to the surface (Hensen's 4/73-100, Nansen's 4/74 net, IONS type net 3/113) (VUČETIĆ, 1961; BENOVIĆ et al., 1981). Two samples were taken successively and preserved by 2.5% neutral formaldehyde. One sample was used for gravimetrical analysis of dry weight of the zooplankton (biomass). Having determined the wet weight, the sample was dried following the VUČETIĆ (1961) method. The calory value of one part of the sample was determined according to PLATT et al. (1969) and WIEBE et al. (1975). The second sample was determined for a qualitative and quantitative analysis of groups and species, applying the method of total and partial counting. The values of the biomass were given in mg m^{-3} , and the values of the quantitative taxonomic analysis were expressed by the number of organisms per vertical haul or in m^{-3}.

Samples of seawater for the bacteriological analysis were taken with bacteriological samplers (Niskin type) and immediately processed in the ship laboratory.

Spreading technique on solid Zo BELL's medium (Zo BELL, 1946) was used in two replications. The number of heterotrophic bacteria was expressed as CFU ml^{-1} (colony forming units) after 7 days of incubation at 20°C.

The distribution of migration and the amount of the small pelagic fish were determined directly by ultrasound detectors (hydroacoustic methods) and by the middle-water trawls. The following instruments were used: SCIENTIFIC SOUNDER EK 38 A, and ECHOINTEGRATOR QM-MK II.

The relative assessment of the fish concentration density was perfomed by the method of sorting echo-signals into categories according to dimensions (mm) and the surface on the echograms and the deflection on the integram.

The assessment of the fish absolute quantity was done by the equation:

$$d = CM$$

whereas d is the mean density of fish (t Nm^{-2}), C is the constant of the echointegrator, M is the mean value (in mm) of displayed on the integrator for the searched area.

The fish biomass was calculated by the equation:

$$W = d\ S$$

whereas W is the total weight of fish (in tons), S is the area (in Nm^2) and d is the average density of fish (t Nm^{-2}).

Data on fish concentration were taken according to permanent routes of detection from 1974 until 1985. The operation frequency of ultrasound detectors was 38 KH2-a.

In more shallow, coastal waters (10-20 m) echosounder operated with a 1 - 3 sensitivity, and in the open area and deeper sea (from 20 m and more) with a 4 - 6 sensitivity.

The "white line" was applied. Wet paper B-21 was used for registering data on small pelagic fish. The fish was identified by the catch analysis from the middle-water trawl. The data were compared with the statistical data on the fish catch.

Data about the catch per fishing day per boat (abundancy index) were divided into eight groups of frequency distribution, per amounts of daily positive catches in tons:

Group	Daily catches (t)	Group	Daily catches (t)
1	0 - 1 000	8	7 001 - 9 000
2	1 001 - 2 000	10	9 001 - 11 000
4	2 001 - 3 000	12	11 001 - 13 000
6	3 001 - 5 000	13	13 001 - +

The mean monthly values of catch per fishing day were calculated by the function:

$$U = U/n$$

whereas U is the catch per fishing day and n is the number of purse-seinings. The corresponding variance was calculated and the index of agregation, i.e. fish concentration was calculated from the relation between the mean monthly value U and the variance.

For ichthyological research of small pelagic fish species representative catch samples from August 1987 and March 1988 were used containing between 28 and 200 specimens per sample. A total of 1081 specimens of small pelagics were analyzed. Catches were studied by standard fishery biology methods.

Data on the fish length refer to the total length. Data on fish lenght in millimetres were placed into centimetres (sardine, mackerel) and halfcentimetre classes (sprat, anchovy). Lower class limits of lenght classes were used and mean length values were corrected.

The sex was determined macroscopically, and seven maturity stages of gonads were determined according to their size, look and colour. The sex and maturity stadium of the smallest specimen was determined by microscope.

The mesentheric fat was determined according to the empirical scale of five stages according to the portion of mesentheric fat in the viscelar cavity.

Standard statistical methods were applied.

The length-weight relationship was calculated by the equation:

$W = a L^b$, and the condition index by FOULTON's coefficient:

$K = 1000 W L^{-b}$, whereas W denotes the weight, L denotes the length of fish, and the constants a and b determine the form of their bodies and the level of growth into length and weight.

11.3. RESULTS

11.3.1. Phytoplankton

11.3.1.1. Primary production

Although only as an information, the first quantitative phytoplankton data for the northern Adriatic were determined as early as the beginning of the century (STEUER, 1902). SCHILLER (1914) speaks of the poor clear water of the eastern Adriatic that unlike the Italian coast has a higher phytoplankton density, but is poorer by the number of species.
The phytoplankton density of the eastern Adriatic in relation to that of the western is considered to be as 2 : 3, while the ratio of the northern and southern, as 12 : 1. BULJAN (1964) divided the Adriatic into 4 productive zones with regard to the concentrations of nutrient salts and depth. According to this division, the shallow northern Adriatic, that is considered, and part of its western coast, belong to the B zone, of a relatively high productivity. PUCHER-PETKOVIĆ (1974) confirmed these zones by the sizes of primary production.

By comparing recent values with the previously assessed, it may be concluded that the production in the open and coastal Adriatic since 1980 onwards has been increasing and that in the open sea it is presently about 50% higher than earlier, and that the increase in the coastal zone is even more outstanding (approx. 60%) (PUCHER-PETKOVIĆ and MARASOVIĆ, 1988).In the open northern Adriatic SMODLAKA and REVELANTE (1983) and SMODLAKA (1985) distinguish a richer, western zone and the central poorer zone. The same division was made for the coastal waters of Istria (Fig. 11.1.).

Fig. 11.1. clearly shows that the photosynthetic activity is much higher in the western than in the eastern part. IVANA and IKA gas fields are located at an area that is greatly influenced by more saline and less rich water from the Central Adriatic, and is only from time to time influenced by the waters from the western part of the northern Adriatic. Data obtained

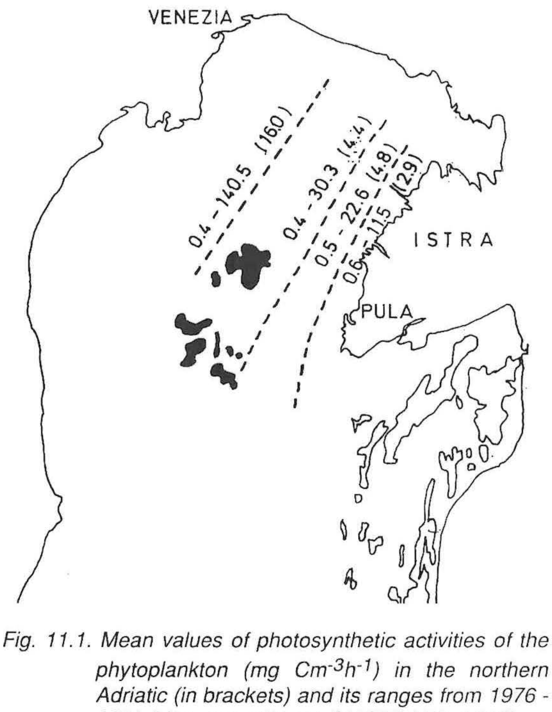


Fig. 11.1. Mean values of photosynthetic activities of the phytoplankton (mg $Cm^{-3}h^{-1}$) in the northern Adriatic (in brackets) and its ranges from 1976 - 1981 (data according to SMODLAKA, 1985)

by the ANDRIJA MOHOROVIČIĆ expedition (1982) from July 1976 perfomed adjacent the IVANA field show low values and confirm the abovementioned.

The seasonal cycle of primary production in the northern Adriatic is controlled by the seasonal cycle and the intensity of the entire solar radiation (REVELANTE, 1975. Fig. 11.2.).

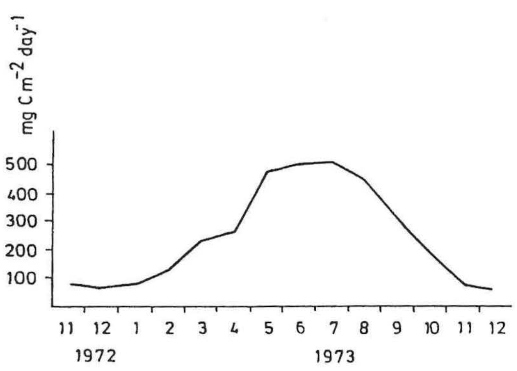


Fig. 11.2. Seasonal cycle of the primary "in situ" production in the North Adriatic waters (REVELANTE, 1975)

11.3.1.2. Biomass

The spatial distribution of the biomass in the northern Adriatic in generally corresponds to the distribution of the primary production. The tendency of decrease of chlorophyll concentration in the direction west-east is clearly evident, as shown on Fig. 11.3. (SMODLAKA, 1985). According to this figure it is possible to conclude that the mean values of the phytoplankton biomass in the western part are about four times higher in general than in the eastern part. With regard to the concentration of chlorophyll *a*, IVANA and IKA gas fields are, as previously said, influenced by the poorer southern waters and have one to two orders of magnitude lower concentrations of chlorophyll *a* than the waters of the northern Adriatic basin.Maximum concentrations of chlorophyll *a*

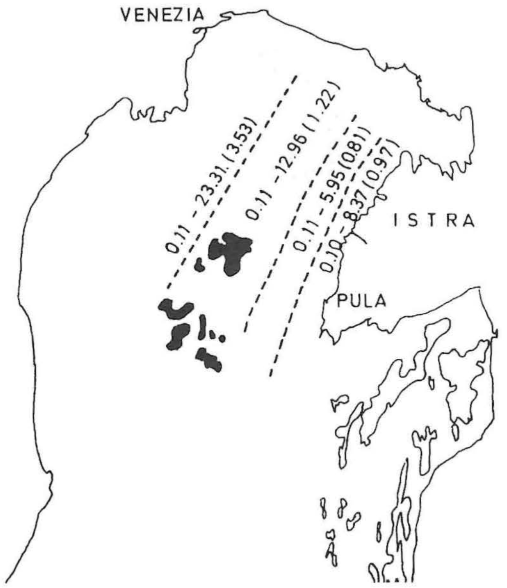


Fig. 11.3. Mean values (in brackets) and ranges of concentrations of chlorophyll a (mg m^{-3}) in the North Adriatic waters from 1976 - 1981 (data according to SMODLAKA, 1985)

observed in November and March, appear in the time of vertical mixing of the water column, and the maximum values in July and September correspond to the period of stratification, and are always higher towards the western coast (REVELANTE, 1975). Because of this, the fluctuations of the phytoplankton biomass are considerably greater in that area. (Fig. 11.3.).

Table 11.1. Concentrations of chlorophyll a (mg m^{-3}) at stations 1, 2, 3 and 4 at the IVANA field in March 1986 and at a somewhat further station 6, that same month in 1982

	1986				1982
	Stations				
m	1	2	3	4	6
0	0.45	0.45	0.50	0.65	0.21
10	0.50	0.42	0.65	0.56	0.36
20	0.68	0.49	0.51	0.55	0.36
35-40	0.44	0.60	1.02	0.67	0.36

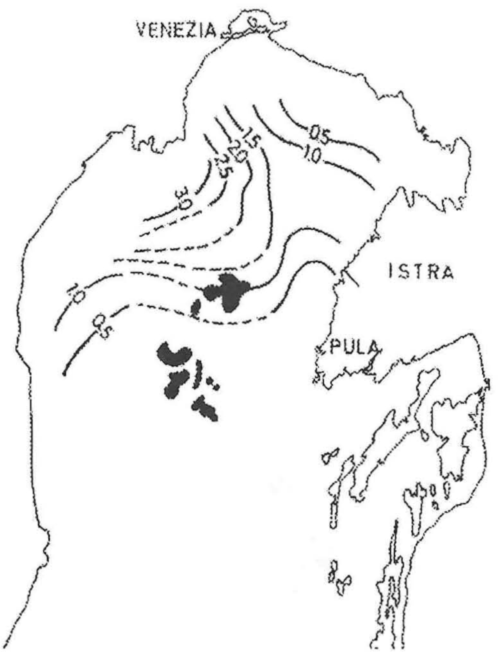


Fig.11.4.a. Surface distribution of chlorophyll a (mg m^{-3}) in June 1973 in the northern Adriatic (REVELANTE, 1975)

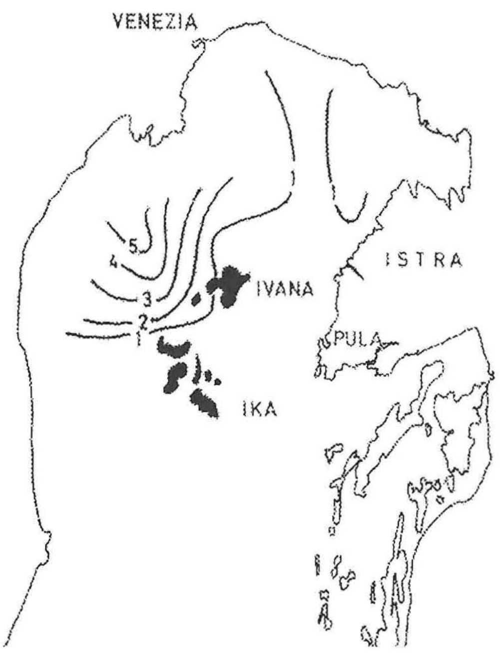


Fig.11.4.b. Surface distribution of chlorophyll a (mg m^{-3}) in November 1972 in the northern Adriatic (REVELANTE, 1975)

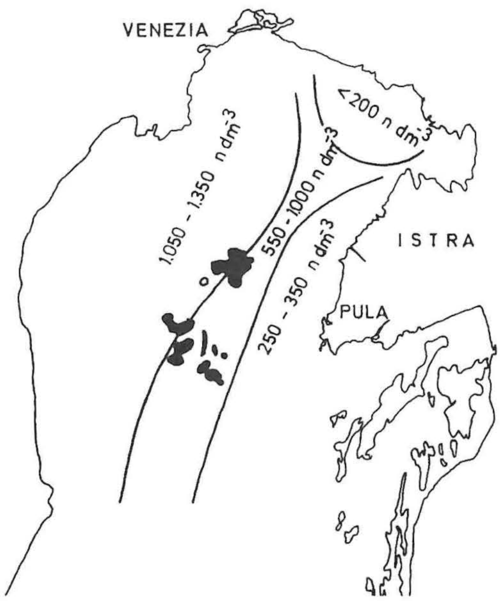
In spring and summer it is characteristic that the water from the Po River, and along with it, increased concentrations of nutrients, can expand to the western Istrian coast, which also reflects on the distribution of the chlorophyll biomass. In November, however, when due to the reduced vertical density gradients, fresh and sea water increasingly mix, the general cyclonic circulation has an impact on higher concentrations of biomass that appear along the western coast in the direction of the South (Fig. 11.4. a, b) (REVELANTE, 1975).

Measurements of the concentration of chlorophyll *a* in the IVANA field are shown on Table 11.1.

Values from March 1982 at station 6 (located somewhat eastern of station 3) are of the same order of magnitude as those from March 1986 at stations 1, 2, 3 and 4. Due to the winter period, these values are otherwise higher than the mean annual values of the biomass for this area.

11.3.1.3. Abundance and species composition

The geographic distribution of the microplankton abundance corresponds to the distribution of the biomass and primary production (Fig.11.5.). Its seasonal cycle is related to the inflow of the Po River as seen on Fig.11.6. These waters reveal a spring and autumn maximum of phytoplankton, where the autumn maximum falls in the period of instability of the water column and the input of nutrients from the sea bottom accordingly. However, in the northern and central part of the Adriatic the past few years have been facing a third summer maximum of phytoplankton that is characteristic for areas influenced by eutrophication from the coast and indicates the input of nutrients through fresh water into the sea surface layer (PUCHER-PETKOVIĆ, 1975; PUCHER-PETKOVIĆ and MARASOVIĆ, 1980; SMODLAKA, 1985).



Fisg.11.5. Annual mean values of phytoplankton abundance(1965) expressed by the number of cells, $nx10^3dm^{-3}$ (ŠTIRN, 1969)

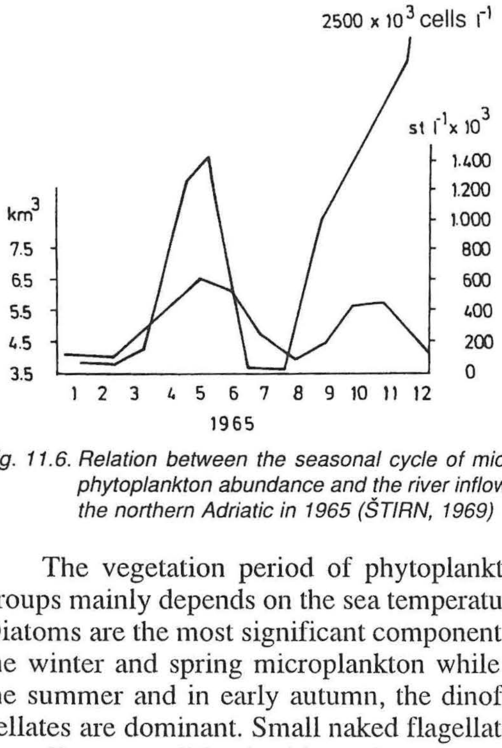


Fig. 11.6. Relation between the seasonal cycle of microphytoplankton abundance and the river inflow in the northern Adriatic in 1965 (ŠTIRN, 1969)

The vegetation period of phytoplankton groups mainly depends on the sea temperature. Diatoms are the most significant component of the winter and spring microplankton while in the summer and in early autumn, the dinoflagellates are dominant. Small naked flagellates, as well as coccolithophorids, main representatives of the nanoplankton, achieve their maximum development in the warmer period of the year.

Regarding the size composition of phytoplankton, the river eutrophication influences the increase of the microplankton/nanoplankton ratio in the direction of the Po River delta (REVELANTE, 1975).

The composition of the phytoplankton in this area was systematically studied as early as the beginning of this century.
About 300 species of diatoms were identified, about 150 species of dinoflagellates, about 100 species of coccolithophorids and 3 species of silicoflagellates. Small naked flagellates are, however, better known from the point of view of quantity rather than quality. The list of species that inhabit these waters may be found in the Catalogue of Adriatic Phytoplankton Species (KERŽAN and ŠTIRN, 1976). With regard to the composition, particularly the dominance of certain genera, differences have been noticed between the western and eastern Adriatic coast (ŠTIRN, 1969). According to this author, from the point of view of dominance of certain genera, the area may be characterized as following:

Winter:
The western-northern type: *Chaetoceros* - *Skeletonema* - *Rhizosolenia*
Eastern type:
Chaetoceros - *Rhizosolenia* - *Thalassiothrix*

Spring:
Western - northern type: *Bacteriastrum* - *Chaetoceros* - *Thalassionema*
Eastern type:
Chaetoceros - *Bacteriastrum* - *Thalassiothrix*

Summer:
No greater differences in the quality between the western-northern and the eastern type of phytoplankton. A mixed composition of representatives of all phytoplanktonic groups is evident, with a considerable presence of nanoplankton flagellates.

Autumn:
No greater differences in the phytoplankton in the western and eastern area and the taxonomic structure is very simple: *Nitzschia* - *Chaetoceros* - *Thalassionema*.

Such spatial distribution of dominant phytoplankton genera confirms the dynamic situation. i.e. a greater connection between the western and eastern part of these waters in the warmer part of the year.

11.3.2. Zooplankton

In the northern, more shallow part of the Adriatic, neritic organisms with a smaller number of species and a larger biomass are dominant, unlike its southern part that is characterized by holoplanktonic species, greater variety, and a lower species abundance. In the richer, northern part of the Adriatic, the number of annual zooplanktonic generations is considerably higher than in other areas.

11.3.2.1. Biomass (dry weight of organic matter)

The biomass of the zooplankton was measured in March 1986 at four stations of the IVANA field. Its values are shown on Table 11.2.

Results of some previous measurements for the northern, Central and southern Adriatic are given for comparison. (Table 11.3.). It is evident that the values of the zooplankton biomass in the northern Adriatic are generally higher than in other parts of the Adriatic which particularly indicates the impact of the Po River onto the amount of zooplankton biomass.

The organic matter of the zooplankton in the northern Adriatic varies from 2.5 to 39.8 mg m^{-3}, whereas extremely high values of organic matter can be obtained only in a very narrow coastal area.

Table 11.2. Dry weight (biomass) of the zooplankton

Station	1	2	3	4
Dry weight mg m^{-3}	9.0	2.0	3.5	1.5

Table 11.3. Dry weight of net zooplankton in mg m^{-3}

	Northern Adriatic	Central and Southern Adriatic
1961 (VUČETIĆ)	14.3	8.1
1979 (VUČETIĆ)	13.8	1.9
1984 (BENOVIĆ *et al.*)	14.2	8.3

11.3.2.2. The composition of zooplankton (taxonomic groups)

By the composition of zooplankton, the northern Adriatic is much behind the Central and southern Adriatic because it has a considerably smaller number of groups as well as species themselves in the same taxonomic group (see map by VUČETIĆ, 1970).

The abundance of main zooplanktonic groups at the IVANA gas field in March 1986 is given in Table 11.4.

Table 11.4. The qualitative and quantitative composition of zooplankton main groups in the IVANA gas field (March 1986) (per vertical haul)

Group	Station				
	1	2	3	4	All stations
Copepoda	35720	19960	16680	12280	84640
Decapoda	23	13	15	32	83
Cladocera	7	0	0	0	7
Ostracoda	0	0	2	0	2
Crustacea varia	0	0	0	0	0
Copelata	41	12	1360	67	1480
Tunicata	0	1	1	0	2
Medusae, Siphonophora	880	56	46	9	991
Chaetognatha	640	24	29	0	306
Mollusca	23	7	6	0	36
Polychaeta	2	0	0	0	2

According to further measurements, the mean annual values of zooplankton groups in that area indicate that Copepoda are represented with 66%, decapod larvae with 16%, Cladocera with 7%, Copelata with 5%, and the remainder are organisms from groups of Tunicata, Medusae and Siphnophora, Chaetognatha, Poychaeta and larval stages of numerous organisms of the pelagic and benthic community.

By the presence of zooplankton organisms, the IVANA and IKA fields belong to the northern Adriatic community. The dynamics of water masses has an impact on stronger seasonal and long-term fluctuations. Oceanic zooplankton species are very rare. The composition is also influenced by the predators. The small pelagic fish, especially in its development stages, prefers organisms from the group of Copelata for its nutrition.

Seasonal fluctuations of Copelata abundance are shown on the following table (Table 11.5.).

From the presence it is possible to determine which species are more of a southern, and which of a northern character and in which way they are influenced by the vertical stratification. This is perhaps best evident on the *Oicopleura dioica*, *O. fusiformis* and *O. longicauda* species. The last one is obviously better represented in the period of stronger advection of the South Adriatic water.

Well evident seasonal differences of quantity are also a feature of the Cladocera group of organisms, particularly *Evadne spinifera* and *Penilia avirostris*. From the seasonal distribution of *E. spinifera* it is evident that it is largely present, particularly in summertime, as well as *P. avirostris* (GHIRARDELLI, 1981).

The influence of advection of the south Adriatic water in certain years is evident in the distribution of some Chaetognatha species. VUČETIĆ (1963) recognized *Sagitta decipiens*, as a good plankton indicator of the southern deep Adriatic waters. In its northern part it can only be found in the inflowing more saline

Table 11.5. The composition and abundancy (No m^{-3}) of Copelata species at position 34 in the IVANA field according to the ANDRIJA MOHOROVIČIĆ expedition 1974-1976.

Species	Spring	Summer	Autumn	Winter
Oicopleura cophocerca	-	-	16	-
O. dioica	2144	400	-	-
O. fusiformis	432	192	1680	672
O. graciloides	144	32	-	128
O. longicauda	48	760	3040	460
Fritillaria borealis	32	-	8	128
F. pellucida	16	-	320	400

water, as later confirmed by GHIRARDELLI (1981). While the southern Adriatic is constantly inhabited by approximately 10 species from this group, the northern part is mostly inhabited by three species: *Sagitta setosa*, *S. minima*, *S. inflata* in seasonal quantities as shown on the next table (Table 11.6.).

In the northern Adriatic, in some seasons there is a larger number of Siphonophora and Medusae. In the last years the scifomedusan species *Pelagia noctiluca* was found in abundance.

Among Siphonophora the most common are *Mugiaea kochii*, *Lensia subtilis* and *Sphaeronectes gracilis*.

The group of Tunicata, that has no greater nutrient value (although consumed by sardine), may appear in larger quantities.

Table 11.6. Seasonal quantities of Sagitta species in the northern Adriatic according to the data of the ANDRIJA MOHOROVIČIĆ expedition, 1974-1976 (per vertical haul)

Species	Spring	Summer	Autumn	Winter
Sagitta inflata	110	110	480	128
S. minima	70	700	670	188
S. setosa	340	680	160	35
Chaetognatha juv.	20	90	29	26

11.3.3. Bacterioplankton

11.3.3.1. Heterotrophic bacteria

Results obtained by winter research (March 1986) on the density of heterotrophic bacteria in the IVANA field show that the mean values vary from 90-166 CFU ml^{-1} (Table 11.7.).

Knowing the seasonal cycle of this group of bacteria it should be underlined that considerably higher values may be expected in summer and autumn. FUKS and DEVESCOVI (1985) determined that the development of the bacteria population in the northern Adriatic reaches its maximum from August until September, while the minimum in the winter period (December - March).

Table 11.7. Density of heterotrophic bacteria (CFU ml $^{-1}$) and its mean values (x) in the IVANA gas field (March 1986)

Station	Depth	CFU ml^{-1}	X
1	0	30	105
	10	5	
	20	120	
	30	25	
	40	345	
2	0	20	166
	10	225	
	20	425	
	30	10	
	40	150	
3	0	95	134
	10	190	
	20	90	
	35	160	
4	0	270	90
	10	35	
	20	60	
	30	45	
	40	40	

The analysis of horizontal distribution of heterotrophic bacteria indicates a greater density of this group of bacteria in the coastal part which is directly related to the greater quantity of organic material that reaches the coastal part from the land. PAVLETIĆ *et al.* (1976) determined a higher density of heterotrophic bacteria in the Pula Bay (an average of 2000 ml^{-1}), than it was measured in the same season at the IVANA gas field. Rather high values of the density of heterotrophic organisms (from 300-45000 ml^{-1}) was registered in Koper and Piran Bays (TURK, 1984).

In general, considerably higher densities of heterotrophic bacteria were determined in the northern Adriatic than in the Central and southern Adriatic. FUKS and DEVESCOVI (1985) found that the number of heterotrophic bacteria in the northern Adriatic varied from 100 to 10000 ml^{-1}, which was three times as much as the values obtained in the Central and southern Adriatic (CVIIĆ, 1955; KRSTULOVIĆ and ŠOBOT, 1983).

11.3.4. Ichthyopelagial

Commercial catches of pelagic fish in the IVANA and IKA gas fields include the following species: sardine, *Sardina pilchardus* (Walb.), sprat, *Sprattus sprattus* (L.) and anchovy, *Engraulis encrasicolus* (L.). Quantities of Atlantic mackerel, *Scomber scombrus* L. and Spanish mackerel, *Scomber japonicus* H. are scarce.

Numerous investigations indicated the existence of a unique population of sardine in the northern Adriatic (MUŽINIĆ, 1954; ALEGRIA-HERNANDEZ, 1983, 1985, 1985a; ALEGRIA-HERNANDEZ *et al.*, 1986;

KRAJNOVIĆ, 1968; KRAJNOVIĆ - OZRETIĆ, 1975; KRAJNOVIĆ *et al.*, 1978; SINOVČIĆ *et al.*, 1991). This sardine population tends to separate this one from the Central Adriatic, not only during the reproduction phase, but also during all life cycles so that they are exploited separately (ALEGRIA-HERNANDEZ and JARDAS, 1985).

11.3.4.1. Distribution and Migration

11.3.4.1.1. Sardine *Sardina pilchardus* (Walb.)

Sardine occupies nearly the entire western Istrian area except the area around the Savudrija peninsula. Several stronger distribution focuses are located closer to the west Istrian coast than in the Italian part.

Sardines are mostly concentrated in the area between Poreč and Pula, starting from 4 NM from the coast to about 12 NM towards the open sea including the IVANA and IKA gas fields.

In autumn, already from November, the sardine starts to migrate, first of all part of its population that is in the northest part, in the Trieste Bay. By the end of December, sardine concentrations can still be registered western of Pula and the Brijuni (Fig. 11.8.). During the winter a greater part of its population leaves the western Istrian area and migrates towards deeper areas, mostly beyond the Dugi otok (KAČIĆ, 1981; ŠKRIVANIĆ and ZAVODNIK, 1973), where the sardine spawns under stable abiotic conditions.

The catch per unit effort (fishing day) varies depending on the concentration level of fish throughout the year. This relation explains the 74.5% of the sardine catch fluctuation in the studied area. The actual population density indicator is the calculated index of sardine agregation: a higher value of the agregation index indicates a greater concentration of fish, and in the case of lower values, the catch per fishing day is lower. Such values are more frequent in warmer months, while the highest values are obtained in autumn (Fig. 11.7.) when the spawning and migration of the sardine begins (MUŽINIĆ, 1952, 1954).

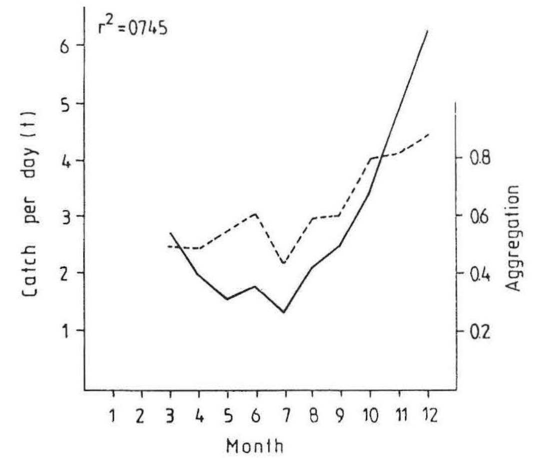


Fig. 11.7. Monthly fluctuations of agregation of the sardine population and the mean catch per fishing day (r^2 = coefficient of determination) in the northern Adriatic

11.3.4.1.2. Sprat, *Sprattus sprattus* (L.)

Unlike the sardine and anchovy, the sprat is almost exclusively found in the northern Adriatic. Already from November, sprat schools start to migrate from the Italian coast towards the western Istrian coast and the Kvarner (Fig. 11.8.). Data indicate that due to

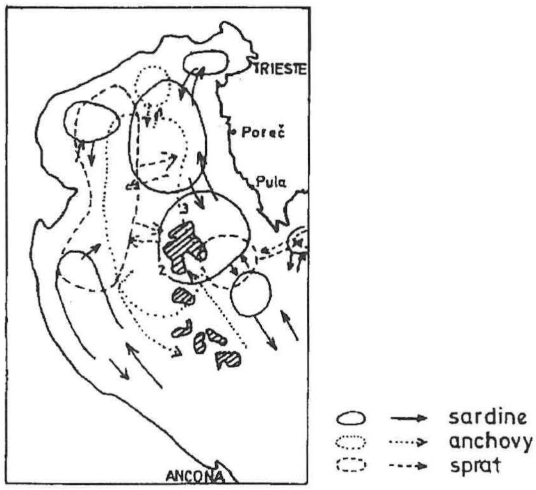


Fig. 11.8. Main focuses of distribution and probable directions of movement of the pelagic fish in the northern Adriatic

spawning, this species remains in the waters of western Istria and the Kvarner during the winter (ZAVODNIK, 1974; REGNER *et al.* 1985; SINOVČIĆ *et al.*, 1991). During the summer it is found at about 25 miles west of the Istrain coast.

Two directions of the sprat have been noticed from the Italian waters towards the Istrian area in autumn and winter. The northern part of the sprat population moves again towards the "green water" of the Po River already in February, while the southern one, retreats much later, or even remains partly in the Kvarner due to unknown reasons so far.

11.3.4.1.3. Anchovy *Engraulis encrasicolus* (L.)

Unlike the sardine, the anchovy is generally a species that is more often found in the upper layers of the sea. The greatest concentrations of this species are found in the northern Adriatic - from the Trieste Bay to the isobath of 50 m. In this area it is found throughout the whole year, with the exception of the coldest months when it usually leaves the Trieste Bay.

During the summer, the greatest part of the anchovy population is located in the area between the west Istrian and Italian waters, creating homogenous schools moving in a large circle (Fig. 11.8.). In the winter it is more dispersed (PICCINETTI, 1970; SINOVČIĆ, 1992). Very often it can be found in areas with small sardine schools.

The rhythm of vertical and horizontal distribution and the pelagic fish migration in the northern Adriatic, mainly depends on the oscillations of temperature during the year (ŽUPANOVIĆ, 1964; KAČIĆ, 1974, 1975).

11.3.4.2. The catch dynamic of small pelagic fish

The sardine makes approximately 77% of the total small pelagic fish catch in the northern Adriatic, while the sprat and anchovy make 21%. However, the catch composition varies seasonally (Table 11.8.) due to the spatial changes of the distribution focus and the possible directions of the population movement of these species (Fig. 11.8.).

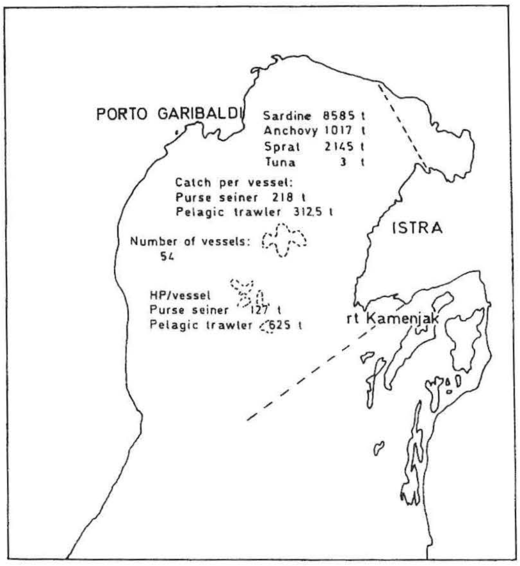


Fig. 11.9. Pelagic resourses of the northern Adriatic: average 10-year catch (1973-1982) of former Yugoslavia fishing boats, number of boats and engine power

Table 11.8. The seasonal composition of small pelagic fish catch in the northern Adriatic from 1975-1985 (% of total catch)

Species	Winter	Spring	Summer	Autumn	Total
Sardine	36.6	86.5	57.3	91.9	76.5
Sprat	11.7	3.6	23.5	3.4	10.5
Anchovy	49.7	5.8	9.6	3.3	10.6
Horse mackerel	1.2	1.9	3.2	1.1	1.7
Spanish mackerel	-	0.2	0.5	-	0.2
Atlantic mackerel	-	0.1	-	-	-

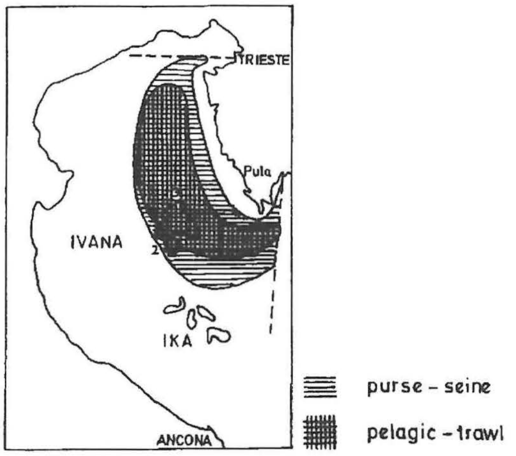


Fig.11.10. Fishing areas of the small pelagics in the eastern part of the northern Adriatic (gas fields)

The annual average of the sardine catch from 1973-1982 in the western Istrian area and Kvarner was 8585 t, sprat 2145 t, and anchovy 1917 t (Fig. 11.9.). Fishing was carried out by purse-seining and middle-water trawls (Fig.11.10.).

11.3.4.2.1. Sardine
Sardina pilchardus (Walb.)

Most of the data applied in this analysis refer to the purse-seining catch of small pelagic fish in the mentioned locations and periods.

The sardine catch in the western Istrian and Kvarner area has shown a constatnt growing trend. The catch growth rate (index) calculated on the basis of the catch data and the fishing effort from 1972-1985 amounted 412.63 tons per year. Apart from the increase of sardine catch, this area shows a slight decrease of the fishing effort. In other areas of the Adriatic, the increasing trend of the sardine catch and the decrease of fishing efforts have also been noticed (ALEGRIA-HERNANDEZ, 1985b, 1986; SINOVČIĆ *et al.* 1991).

The frequency of the sardine purse-seining catch per fishing day has an extremely negative bimodal distribution, with modal values that correspond to the smaller amounts of the catch (Fig. 11.11.). Such distribution reflects the characteristic behaviour of the species in relation to the formation of smaller or bigger school concentrations. Year after year, the distribution shows a tendency of smaller placing to the right because the number of catches of greater amounts per fishing day increases which was already noticed at the sardine catch in other areas of the Adriatic (ALEGRIA-HERNANDEZ, 1985b, 1986). That indicates an overall increase of population in the period of growth (ALEGRIA-HERNANDEZ, 1983a, 1984, 1986).

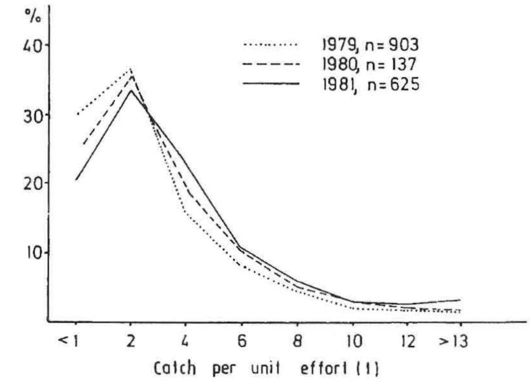


Fig.11.11.Fluctuation of frequency distribution catch per unit effort (purse-seining day) of the sardine from 1979 - 1981 in the northern Adriatic

Taking into consideration that the sardine catch is seasonal, the seasonal distribution of the catch frequency per fishing day has been analyzed (Fig. 11.12.).

In warmer months, smaller amounts prevail inspite of the greatest fishing efforts. This

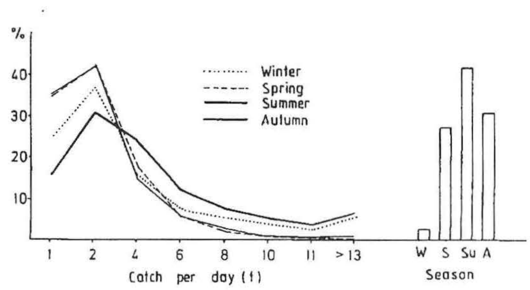


Fig.11.12. Seasonal frequency distribution changes of the sardine catches per fishing day from 1979 to 1981 in the northern Adriatic

Table 11.9. Seasonal variations of the mean catch per fishing day (Ū) and the corresponding maximum catch per fishing day (U-max) of the sardine (in kilograms) for 1979-1981 in the northern Adriatic.

Season	1979		1980		1981	
	Ū	U-max	Ū	U-max	Ū	U-max
Winter	2356	3330	2521	15180	4995	23145
Spring	1978	13236	2527	17687	2225	16426
Summer	2064	13975	2860	17054	1980	12166
Autumn	4410	23970	4155	20500	5688	29184

indicates that the population is dispersed in a wider area. However, in autumn, the percentage of catch is greatest, which corresponds to the period of fish concentration in larger schools. The winter period data are very scarce, particularly for March. The fish population is probably less available during its migration. The calculated seasonal sardine abundancy indexes, that express the population abundance at a certain moment, are given in Table 11.9. Compared with the maximum catch values per fishing day in a certain season, they confirm the described changes of the sardine population concentrations.

11.3.4.2.2. Sprat, *Sprattus sprattus* (L.)

Late autumn is the main catch period of the sprat, although the greatest catches per unit effort occur at the end of summer. (Table 11.10.).

Although it is difficult to determine the changes of the population distribution from available data, the frequency distribution of catches per fishing day (Fig. 11.13.) indicates a larger concentration particularly in autumn, i.e. during the gonad maturation of the sprat (ZAVODNIK, 1974). It seems though, that the variations of the catch per fishing day only partly reflect the natural changes of the population because the catch is determined by the market demand. From 1975 until 1985 the total catch of sprat had a low trend of annual growth and the index of increase amounted 166 tons per year during the 1975-1985 period.

11.3.4.2.3. Anchovy *Engraulis encrasicolus* (L.)

Although the anchovy is a widely represented species, particularly in the northern Adriatic, from 1975 until 1983 its catch was

Table 11.10. Seasonal variations of the mean catch per fishing day (Ū) and the corresponding maximum catch per fishing day (U-max) of the sprat (in kilograms) for 1979-1981 in the northern Adriatic.

Season	1979		1980		1981	
	Ū	U-max	Ū	U-max	Ū	U-max
Winter	-	-	2591	5112	4062	6226
Spring	3177	14000	975	2785	1172	8875
Summer	7558	27483	3420	13582	8552	35127
Autumn	6705	21316	3800	16272	2845	8195

Table 11.11. Seasonal variations of the mean catch per fishing day ($\bar{U}$) and the appropriate maximum catch per fishing day (U-max) of the anchovy in (kilograms) from 1979 until 1981 in the northern Adriatic

Season	1979		1980		1981	
	$\bar{U}$	U-max	$\bar{U}$	U-max	$\bar{U}$	U-max
Winter	-	-	8995	29780	4132	14649
Spring	604	5783	774	9786	564	2840
Summer	859	3481	860	16452	934	9010
Autumn	2004	9868	1120	6220	2411	13024

characterized by a decrease (index of decrease = -39.2 tons per year) and a large variability (SINOVČIĆ, 1992). Although anchovy catches bear seasonal characteristics, the best catches are realized in summer and autumn, during the spawning period of this species (SINOVČIĆ, 1978).

The mean catch per fishing day is mostly low with a very small percentage of larger amounts of catches (Table 11.11.). Larger catches per fishing day often occur in wintertime.

From the frequency distribution of the anchovy catch per fishing day (Fig. 11.13.), it is evident that the most numerous catches of small amounts mostly occur in springtime and summertime, while greater catches are realized in wintertime.

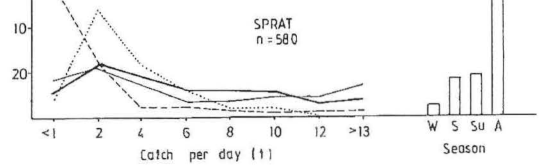


Fig. 11.13. Seasonal frequency distribution changes of the sprat and anchovy catches per fishing day from 1979 - 1981 (n = number of purse-seinings) in the northern Adriatic.

11.3.4.2.4. Other species of small pelagics

Other species of small pelagic fish are very poorly represented in catches in the waters of western Istria and the Kvarner (Table 11.8.). The horse mackerel which is a semi pelagic species is widely present in the Adriatic and forms about 2% of commercial catches. It is caught all year round. In the western Istrian region, the greatest catch is reached in summertime and in the beginning of autumn. The daily catch is usually very low in autumn, but can sometimes reach high amounts. The Spanish mackerel appeared in insignificant quantities mainly in springtime and summertime; the mackerel was nearly not caught at all during this research.

11.3.4.3. Stock assessment

Assessments of the quantity of small pelagic fish performed by echosounder and echointegrator (hydroacoustic method) show two values: the relative and absolute fish abundance (Table 11.12.).

Table 11.12. The number of small pelagic fish concentrations per survey unit (MAX/M=maximum number, $\bar{X}$/M=mean number) and the relative (d) and absolute quantity (W) of fish in the northern Adriatic (Cape Kamenjak - Porto Garibaldi) during 1974-1982. The data were obtained by means of Simrad Scientific sounder EH 38.2 Khz and Echointegrator MARK-II-QM (MV=microvolt).

		Number of fish concentrations (max.) (mean)		Echointegrator reading (MV/mm/Nm)			Quantity Relative (d) Absolute (W)	
Area	Area (Nm^2)	MAX/M	$\bar{X}$/M	A	B	(A+B)	(t/Nm^2)	t
Northern Adriatic Cape Kamenjak - Porto Garibaldi	1023	5.36	1.48	1.18	1.96	(3.14)	58.30	27000
				0.41	1.04	1.45*	54.00*	31000*
				$\bar{x}$=0.80	$\bar{x}$=1.5	$\bar{x}$=2.30	$\bar{x}$=56.15	W=58000

* data of Italian waters

The relative abundance of fish, that is the maximum number of fish concentrations (MAX/M) in the western area (northern of the Cape Kamenjak - Porto Garibaldi area) was 5.36 concentrations per nautical mile. The mean number of small pelagic fish concentration (X/M) in that area was 1.48 concentrations per nautical mile.

The absolute abundance of fish (stock assessment) (d) in the mentioned area was 56.15 tons per Nm^2.

The absolute quantity (W) was 58 000 tons in the area northern of Cape Kamenjak - Porto Garibaldi (Table 11.12.).

On the basis of three-year studies by pelagic trawl, GRUBIŠIĆ et al. (1974) assessed that the quantity of small pelagic fish in the western Istrian waters was about 37 000 tons.

In earlier researches KAČIĆ (1984) calculated the stock of 122 000 tons of sardines for the northern Adriatic.

According to ZAVODNIK (1974) the western Istrian and Kvarner waters have a large sprat stock, estimated to approximately 100 000 tons.

According to the direct method performed by ŠTIRN (1969), the anchovy biomass in the northern Adriatic was estimated to 250 000 tons.

11.3.4.4. The population composition of small pelagic fish

11.3.4.4.1. Sardine *Sardina pilchardus* (Walb.)

The representative sample of the sardine from the IVANA gas field comprised 200 specimens. Their total lengths varied between 12.8 and 15.5 cm (Fig. 11.14). The unimodal

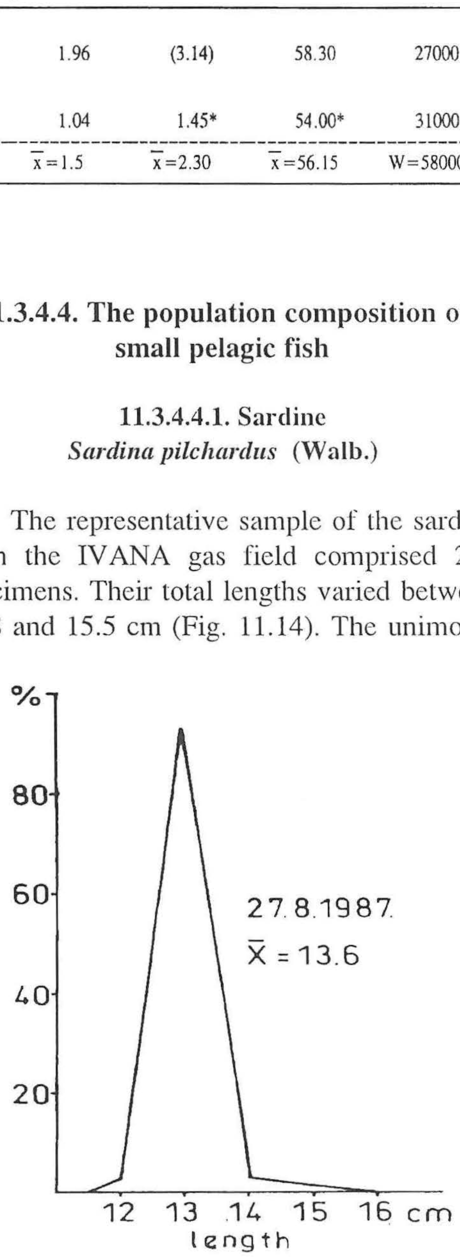


Fig.11.14. The sardine lengthwise distribution in the middle water trawl catch sample in the IVANA gas field

Table 11.13. Mean values of the length ($\bar{x}$), standard error of arithmetic mean ($s_{\bar{x}}$)standard deviation (s), coefficient of variability (k.v.) of samples of the sardine, anchovy and sprat in various areas of the northern Adriatic.

	Date	Region	n	♂/♀	$\bar{x}$	$s_{\bar{x}}$	s	k. v.
Sardine	27.8.1987	Gas fields	200	1.86	13.6	0.0385	0.3851	2.8
	25.3.1988	Kvarnerić	56	2.11	15.4	0.1588	1.1887	7.7
	28.3.1988	Velebit Channel	57	1.71	16.0	0.1775	1.3400	8.3
	28.3.1988	Velebit Channel (night)	28	1.80	17.3	0.1947	1.0300	3.8
	T o t a l		341					
Anchovy	24.3.1988	Kvarnerić	52	0.41	15.1	0.1081	0.7793	5.1
	25.3.1988	Kvarnerić	50	0.61	14.6	0.0908	0.6423	4.4
	26.3.1988	Velebit Channel	37	0.68	15.1	0.0599	0.3646	2.4
	30.3.1988	Velebit Channel	48	0.66	15.1	0.0445	0.3083	2.1
	T o t a l		187					
Sprat	24.3.1988	Kvarnerić	58	0.21	12.8	0.0172	0.1313	1.0
	24.3.1988	Kvarnerić (night)	72	0.18	12.9	0.0763	0.6471	5.0
	25.3.1988	Velebit Channel	54	0.20	12.8	0.0763	0.5485	4.3
	26.3.1988	Velebit Channel	153	0.26	12.9	0.0491	0.6079	4.7
	28.3.1988	Velebit Channel	26	0.44	13.1	0.0855	0.4358	3.3
	28.3.1988	Velebit Channel	102	0.38	12.7	0.0939	0.9482	7.4
	30.3.1988	Velebit Channel	78	0.53	12.8	0.0693	0.6119	4.8
	T o t a l		543					

and symmetrical distribution with a narrow amplitude and a low coefficient of variability (k.v.-2.82.) indicate a greater homogeneity of the sardine in this area. The modal length value is 13.0 cm, the mean value is 13.6 - 0.0385 with the standard deviation of s = 0.3851. The lengthwise composition of the sardine would likely be somewhat different should the analysis of length be performed on specimens caught by purse-seining (ZEI, 1977), although, we believe, not greatly.

The catch mostly consisted of male fish; the index of sex ratio was 1.86 in favour of the males (Table 11.13.).

In order to determine the proportional length-weight increase of the sardine, the ratio which is important when assessing the population abundance of a specific species, the functional regression between the lenght and weight was applied. All analyzed samples of the sardine were of equal physiological condition - reposing state in the sexual cycle (maturity stages I and II) - which is particularly important.

The mesentheric fat content was considerable: stage 4 prevailed at nearly all sardine samples.

In the variation of the length-weight ratio of the smallest sardines (Fig. 11.15.), the greatest proportional increase of length can be seen. Such characteristic of growth is also seen on sardine shorter than 10.0 cm, which was earlier evidenced for this species in the Central Adriatic (SINOVČIĆ, 1986). After a length of 10.0 cm, the sardine grows nearly isometrically lengthwise and weightwise. The change of the proportionally greater increase of weight of the sardine occurs above 14.0 cm whereas its weight considerably increases. At that lenght the entire sardine population is completely sexually mature (SINOVČIĆ, 1984). The coefficient of correlation between the length and weight of the sardine specimens from this area

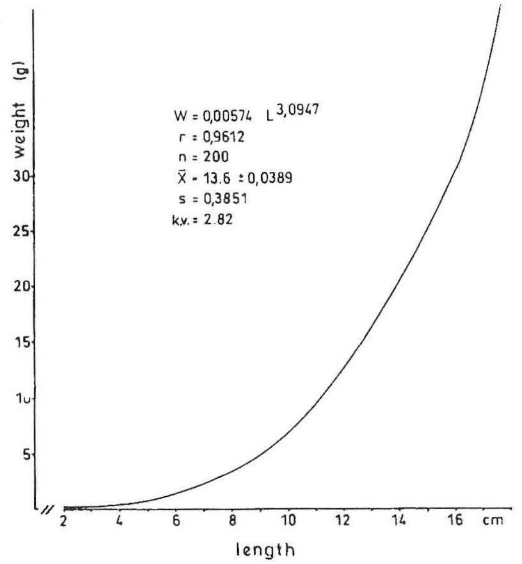


Fig. 11.15 . The sardine length-weight relationship in the IVANA gas field

is very high and considerable (r = 0.9612, P<0.001), and the regression coefficient indicates an isometrical, ideal length-weight ratio. The mean value of FOULTON's condition coefficient was 6.52.

If comparing the total lengths of sardine specimens from this area to the ones from the coastal waters of the northern Adriatic, i.e. the Kvarnerić and the Velebit Channel caught by bottom trawl six months after the cited period, the total length distribution of the sardine may be noticed. (Fig. 11.16.). The distribution curves of total sardine lengths (114 specimens) from this area are bimodal and asymmetrical. The total lengths in general varied from 13.8 to 19.1 cm. The length amplitude was wider than that of the sample from the IVANA gas field and the lengths varied a greater deal as well. The coefficient of variability (k.v.) was between 5.8 and 8.3 cm. The population is characterized by dominant modes from 15.0 and 17.0 cm and in the case of same lengths, secondary modes were evidenced. Mean length values varied between 15.4±0.1588 and 17.5±0.1947.

Data on the sardine catch composition in general from the studied areas indicate the presence of sardine specimens of smaller

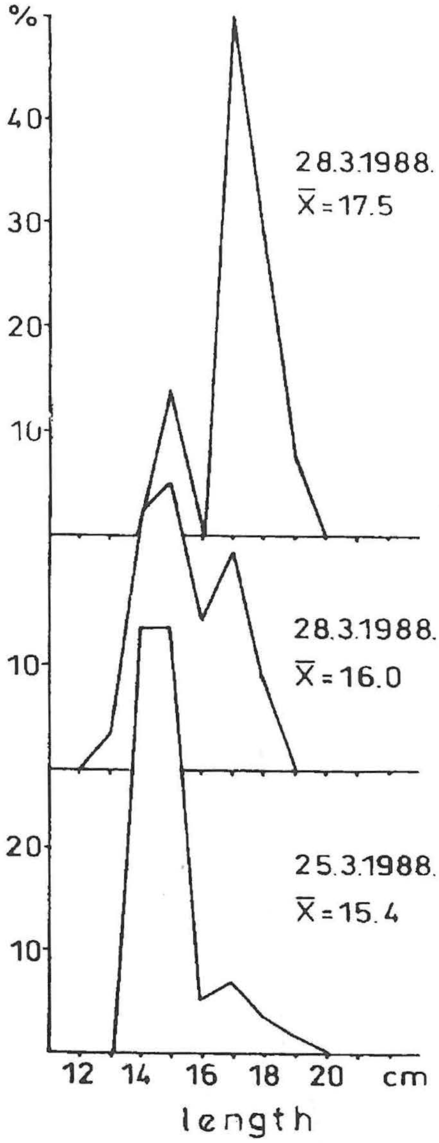


Fig. 11.16. Sardine specimens lengthwise distribution from bottom trawl catch samples in the Kvarnerić and the Velebit Channel (detailed data on Table 11.13)

length in the western Istrian area than in the Kvarnerić and the Velebit Channel. These differences are probably caused by the relation between the sardine length and the sea depth.

In all samples males extremely predominated. The sex ratio varied between 1.7 and 2.1 in favour of the male. Since the catches were carried out by bottom trawl, the presence of sexes was most probably due to the greater presence of the male in the lower sea layers at the time of prematuration.

11.3.4.4.2. Anchovy
***Engraulis encrasicolus* (L.)**

The anchovy was found together with the sardine in all bottom trawl catches.

Four samples of the anchovy catch were studied with a total of 187 specimens from catch samples from the Kvarnerić and the Velebit Channel. Each catch consisted of a range of 37 to 52 specimens. In all anchovy catches, the female was predominant. The sex ratio varied between 0.41 and 0.68 in favour of the female. Proportionally there were more females in the catch from Kvarnerić, and the least in the catch from the Velebit Channel. All specimens showed maturity stage III that denotes the beginning of sexual maturity. This statement is in accordance with the facts about the gonad stages of the anchovy at this time of the year (SINOVČIĆ, 1978).

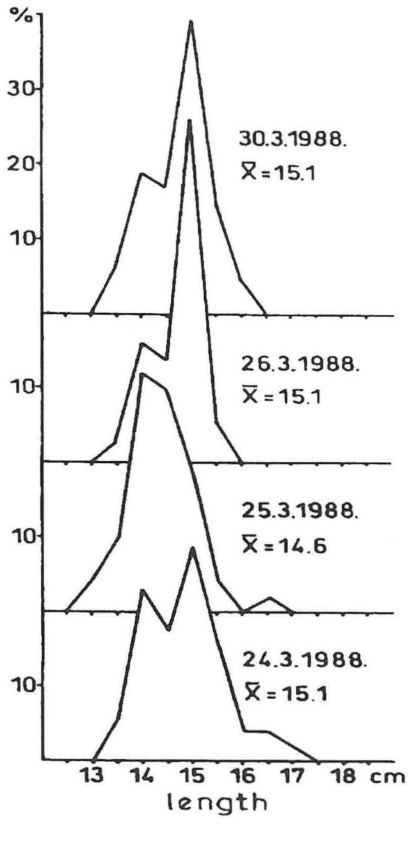


Fig. 11.17. Anchovy lengthwise distribution in bottom trawl catch samples in the Kvarnerić and the Velebit Channel (detailed data on Table 11.13)

The mesentheric fat was slightly visible in the viscelar cavity.

The total length of the anchovy in general varied from 13.4 and 17.0 cm (Fig. 11.17.) with a bimodal and asymmetrical distribution. The dominant mode of 15.0 was evidenced at all samples except catch samples dated March 25, 1988 that had a dominant mode of 14.0. The mean values of the total length were very similar; they varied from 14.6±0.0908 to 15.1±0.1081 while the values of standard deviations were between 0.3083 and 0.7793. The catch on March 25, 1988 from the Kvarnerić consisted of smaller fish.

11.3.4.4.3. Sprat, *Sprattus sprattus* (L.)

The sprat is a small pelagic fish species that prefers colder and less saline seawater (ZAVODNIK, D. and ZAVODNIK, N. 1969; SINOVČIĆ *et al.*, 1991). Therefore the greatest part of its population is distributed in the northern Adriatic.

Its commercial value is much less than of the sardine and the anchovy.

Seven samples of sprat catches were studied with a total of 543 specimens, which in certain catches varied from 26 to 153 specimens.

The total lengths of all sprat specimens in general varied from 11.5 to 15.0 cm, which is the greatest length of sprat ever recorded in the Adriatic. The mean lenghts of the sprat from certain samples were nearly identical - they varied from 12.7±0.0939 to 13.1±0.0855 (Fig. 11.18.) with standard deviations between 0.1313 and 0.9482. The length variation amplitude was mostly narrow, and the values of the coefficient of variability of the total length were both very low (k.v.=1.0) and also very high (k.v.=7.4).

The length distribution curves were mostly unimodal and symmetrical except for the catches dated March 24 and 25, 1988. The dominant modal value at 12.5 cm was noticed in the majority of the catch.

In sprat catches, females were predominant: the sex ratio varied from 0.18 and

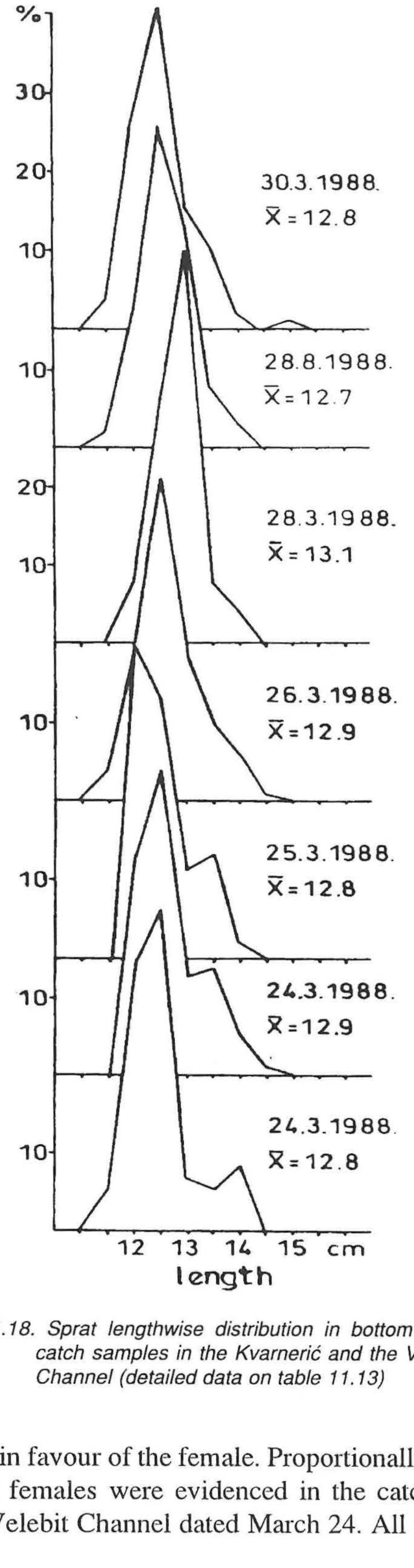


Fig.11.18. Sprat lengthwise distribution in bottom trawl catch samples in the Kvarnerić and the Velebit Channel (detailed data on table 11.13)

0.59 in favour of the female. Proportionally the most females were evidenced in the catch in the Velebit Channel dated March 24. All sprat samples were already spawned (stage VII), and by the end of March they did not contain mesentheric fat. Such stage of the gonad maturity in the mentioned time of study was in accordance with earlier statements made by ZAVODNIK (1970) regarding sprat spawning in wintertime (SINOVČIĆ et al., 1991).

The sprat mainly spawns in the Kvarner area (GAMULIN and HURE, 1983), from where, in springtime, it migrates towards summer habitats of the shallow northern Adriatic, while the lesser part of the population remains in the area of Kvarner and Rijeka.

According to ZAVODNIK (1974) there are two sprat subpopulations in the northern Adriatic.

11.3.4.4.4. Atlantic mackerel *Scomber scombrus* (L.)

During our studies only one bottom-trawl catch from the northern part of the Kvarnerić consisted of 10 Atlantic mackerel specimens. Their lenghts were from 15.6 and 17.0 cm with a modal value at 16.0 cm. In the mentioned samples it was not possible to determine the sex due to undeveloped gonads, which may indicate that these were juvenile mackerel specimens, that did not yet reach the first sexual maturity (SINOVČIĆ, 1995). Besides the mentioned examples, also evidenced was a specimen 26.7 cm long that greatly departed by length from the other specimens and that was spawned (stage VII). This is in accordance with earlier finds by LISSNER (1939) and SINOVČIĆ (1995) who state that the Atlantic mackerel breeds in wintertime in the northern Adriatic in the Rijeka Bay, Kvarner and the northern part of the Kvarnerić. These areas are known as the best fishing grounds of this species, apart from those in the waters of western Istria (GAMULIN, 1954, 1964; SINOVČIĆ, 1993).

The presence of mesentheric fat was not found in the viscelar cavity at neither of the Atlantic mackerel specimen.

11.4. CONCLUSIONS

Analyzing the phytopankton parametres it may be said that the primary production in the studied basin is 1 - 2 orders of magnitude higher than the one at the open sea of the central and southern Adriatic, and that the western side of that basin is richer than the eastern Istrian coast.

The IVANA and IKA gas fields are mainly influenced by the poorer waters from the south. The spatial distribution of the studied parametres indicates only the temporary influence of the waters from the western coast.

The zooplanktonic biomass is also higher, but the diversity is much less than in the open sea of the southern Adriatic.

It is assumed that a great number of different larval stages of the zooplanktonic organisms comes from the central and southern Adriatic, some of which, because of the circulation of the currrents, return to their original area. This is why the eastern part of the northern Adriatic is an important transit area for meroplanktonic as well as holoplanktonic organisms. Hence the duality of the significance of this area as a supplier of species to other areas and as the "cemetery" for some alochthonous elements of the plankton from the south.

The northern Adriatic, including the IVANA gas field, proved to have, for other planktonic components as well, a much higher density of heterotrophic bacteria (up to three times as much) than in the central and southern Adriatic.

The sardine was predominant in small pelagic fish catches in the waters of western Istria and the Kvarner. The sprat and anchovy are also represented, along with other species such as the horse mackerel, Atlantic mackerel and the Spanish mackerel.

With regard to the behaviour of the small pelagics, a clear spatial and temporal movement of the sardine has been noticed from the Trieste Bay towards the south and vice versa, the sprat from the Italian towards the western Istrian coast and the Kvarner and vice versa, the anchovy from the western Istrian coast towards the Italian coast and vice versa.

The most frequent concentrations of small pelagic fish are found in the northern part of the Adriatic, i.e. in western Istria. Changes in the concentrations of the sardine follow a certain cycle that corresponds to its movement: in the warmer part of the year the population is spatially dispersed, while autumn is characterized by the appearance of larger schools of fish.

The estimated absolute abundancy of the sardine stock in this area during these studies was 56.16 tons Nm^{-2}.

The greater part of the sardine population at that time was in the process of growth.

Sardine catch has a seasonal character. Autumn is dominated by greater catches per fishing day which corresponds to the period of concentration of fish in greater schools. The catch variations are significantly connected with the agregation level of the fish population.

The sardine from the west Istrian waters is very homogenous regarding its length (modus 13.0 cm), isometric increase of length and weight, FOULTON's condition coefficient of 6.25, the predominance of the male unlike the sardine from the Kvarnerić and the Velebit Channel which is heterogenous regarding its length. Sardine from this area is characterized by modal length values of 15.0 and 17.0 cm. Differences in size between the sardine from the west Istrian waters on the one hand and that from the Kvarnerić and the Velebit Channel on the other, indicate the relation between the sardine length and sea depth.

All catches were dominated by males with gonads that characterize the reposing state in the sardine sexual cycle, and it was concluded that male sardines in this phase were more represented in deeper layers.

As for the northern Adriatic anchovy, a great homogeneity was noticed regarding its length (modal values 14.0 and 15.0 cm) and a greater presence of females in all catches which is probably caused by the greater presence of female anchovy in deeper layers of the sea during prematuration.

The length ranges of sprat, their modal values as well as the mean values of their lengths indicate a considerable homogeneity of the sprat at the time of studying and at the research area. Spawned females dominated in all catches, which indicates that after spawning females were present in deeper layers. In the northern Adriatic the sprat has two subpopulations.

Regarding the maturity stages of the Atlantic mackerel, specimens up to 17.0 cm comprised by this study during their spawning time (winter, beginning of spring), they did not reach their first sexual maturity.

11.5. REFERENCES

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Ekološka studija plinskih polja u sjevernom Jadranu

Ekološke osobine pelagijske zajednice

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KRATKI SADRŽAJ

Na osnovi obrađenog materijala iz ožujka 1986.g., kao i ranije prikupljanih te statističkih podataka, prikazana su osnovna svojstva pelagijske zajednice. Radi svojeg načina života, organizmi ove zajednice promatrani su u širem prostoru kako bi se bolje definiralo područje plinskih polja.

Doneseni su podaci o vremenskoj i prostornoj distribuciji primarne proizvodnje, koncentracije klorofila *a*, zooplanktona i bakterioplanktona.

Glavne vrste male pelagijske ribe (srdela, papalina, brgljun) promatrane su s obzirom na sezonsko-prostorno kretanje, odnosno njihove koncentracije.

Procijenjena je apsolutna abundancija stoka srdele. Analize ulova učinjene su s obzirom na povezanost sa stupnjem agregacije populacija.

Studirana je dužina, izometrijski porast dužine i težine, FOULTON-ov koeficijent kondicije, te odnosi spolova kod nekih vrsta male plave ribe.