United Nations
Environment
Programme

UNEP(OCA)/MED WG.55/5
9 September 1992

Original: ENGLISH

MEDITERRANEAN ACTION PLAN

Meeting on Implications of Climatic Changes on
Mediterranean Coastal Areas (Island of Rhodes,
Kastela Bay, Syrian Coast, Malta and Cres/Losinj Islands)

Valletta, 15-19 September 1992

IMPLICATIONS OF EXPECTED CLIMATIC CHANGES ON CRES/LOSINJ ISLANDS

UNEP
Athens, 1992

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EXECUTIVE SUMMARY

The selected Cres-Losinj archipelago is the greatest island group in the Adriatic region.

The Cres-Losinj archipelago consists of two medium-sized and several small islands, which display a variety of the features typical of Mediterranean, limestone and sandy islands.

The ecosystems of these island are very complex and vulnerable entities of inter-related species, where every aspect of climate change and sea level rise will cause a wide range of environmental impacts.

Diversity of relief, climatic, vegetation, landscape, flora and fauna on the relatively small area distinguish this archipelago from the others making it more interesting and specific.

The Cres-Losinj archipelago has maritime climate, with rather warm summers and no cold winter. The average temperature in the warmest month is 22 °C and in the coldest 6-8 °C - January. The prevailing winds are bora (NE) and scirocco (SE). Daily average of 10 sunshine hours.

The only fresh water resource is the Lake of Vrana with a surface area of 575 hectares - 10 m above sea level, maximum depth 75 m, which is 65 m below sea level;

The marine environment around the Cres-Losinj archipelago is typically oligotrophic. It is characterized by high salinity surface temperature fluctuation, low primary productivity, and variety of marine organisms. Small blue fish, white fish and scampi are the most important commercially exploited species.

The area is under the influence of meteorological , oceanographic and hydrological changes occurring in a much larger region, The hydrographic and biological properties of the whole area are under the influence of the central Adriatic during most of the year, although during summer water exchanged with northern Adriatic may play substantial role. Aside from the waters around the northern parts of Cres Island, which are affected by the freshwater discharges in the Kvarner region, there is no major local influence on the ecosystem.

In 1991 the archipelago was inhabited by 11,369 people, living in 39 settlements. Twelve of these settlements, with 90 per cent of the archipelago's total population, are in the coastal belt. Mali and Veli Losinj (7,500 inhabitants) and Cres (2,200 inhabitants), both on the coast, are the largest settlements.

Scenario for predicted climate change in the Cres-Losinj archipelago deduced from scenarios by IPCC and the University of East Anglia adapting the following figures:

- Losinj	2030 AD	- temperature+1.6 to +1.8 °C
		- precipitation0 to -5%
		2050 AD- temperature+1.4 to +2.8 °C
		- precipitation0 to -9%
		2100 AD- temperature+1.8 to +5 °C
		- precipitation0 to -15%
- Cres		2030 AD- temperature+1.8 to +2.0 °C
		- precipitation0 to 5%
		2050 AD- temperature+1.5 to +3.3 °C
		- precipitation0 to 9%
		2100 AD- temperature+2 to 5.5 °C
		- precipitation0 to +15%
- sea level rise	2030 AD	+18 +/- 12 cm
		2050 AD+38 +/- 14 cm
		2100 AD+65 +/- 35 cm

On the basis of the predicted climate changes implications and most vulnerable areas are identified though substantive sections of the study.

Changed climate conditions will induce the changes in atmospheric circulation, what might have the effect on redistribution in time and space, changes in intensity of winds, cloudiness and insolation, as well as on the frequency of more intensive extreme climate changes.

In spite of relative certainty of sea level trends in the area of the Cres-Losinj archipelago, due account should be paid to distinguish in what measure the sea level rise is the result of higher atmospheric pressure of the subsiding of land in this part of the Adriatic.

With regard to the gradation of climate changes by 2050, there is a great possibility for natural ecosystems to be able to adapt, as well as for managed ecosystem although in another way.

The difficulties will probably arise from further temperature increase of 3 °C and the sea level rise of 100 cm in the second half of the next century.

However, relatively slighter consequences of climate changes combined with more intensive human activities (population increase, development of industry, tourism etc.) could result in problems even before the year 2050.

Climate change impact, especially in the second half of the next century, could induce stronger atmospheric pollution originating from Rijeka industrial basin and exceed the permissible limits, as a consequence of circulation changes and intensified extreme situations.

The forest cover will be endangered by increased forest fires.

The most important impact will be shown in hydrosphere and freshwater ecosystem, what might result in fact that the only water supply source on island - the Vrana Lake, won't be able to satisfy future demands as for increased evaporation.

Changes in precipitation regime will have the negative impact on the most important agricultural activity, i.e. on the livestock, being predicted in natural conditions where sheep use natural or man-made watering places.

Fighter seawater temperatures and freshwater inputs will increase the primary productivity, with positive consequences for fisheries.

The most significant impact will be felt by urban areas next to the coastline, with 90% of the total population living in 12 settlements.

About 35 hectares of urban area, carrying about 600 buildings and housing about 13 per cent of the archipelago's present population, will be affected by sea level rise.

Industry, mostly shipyards, which are located in the immediate coastal area, will be affected, too. The same works for services and installations related to the road network, a considerable part of it being in the coastal area. Ports and marinas will be affected, too.

The rise of sea level will also cause problems in the existing coastal sewage network and it will have to be adapted very soon (probably even now).

Climate change impact to the population flow and natural growth probably won't suffer any significant consequences.

The health of the island population is not expected to be affected by climate change by 2050.

The questionnaire results on population attitude related to the climate change conditions indicate a realistic and pragmatic view, with no fear for dramatic events.

According to the evaluation of the climatic change impacts, certain actions are to be established in order to avoid or mitigate the negative effects resulting from them

Following recommendations and suggestions could be accepted:

- it is important to incorporate certain measures, suggested by the finding of this study, into the development policy of physical planning
- establishment of system of constant monitoring of the status of the environment on local, regional and national level
- organizing environmental management in cooperation with local inhabitants responsible decision makers, local and international experts
- starting a longitudinal research programmes adoptions of social and economic systems to changes resulting from climatic conditions.

1. INTRODUCTION

1.1 Background

The greenhouse effect is among Man's most pressing environmental problems, one which presents major scientific challenges across a wide range of disciplines. Changes in global climate between now and the middle of the 21st century are likely to be dominated by the influence of global warming due to increasing concentration of carbon dioxide and other gases in the atmosphere. These greenhouse gases individually and collectively change the radiative balance of the atmosphere, trapping more heat near the Earth's surface and causing a rise in global-mean surface air temperature and as a consequence substantial global warming is virtually certain.

The question of the probable climate warming in the next few decades is a question concerning both the world in general and the Mediterranean in particular.

In spite of uncertainties surrounding predicted climatic changes, greenhouse gases seem to have accumulated in the atmosphere to such a level that the changes may have started already and their continuation may now be inevitable.

There is a consensus in the scientific community that if allowed to continue to build up, a doubling of the greenhouse gases concentration (relative to the pre-industrial era) will occur sometime in the 21st century, possibly as early as 2030 AD. The recent Second Climate Conference (Geneva, 29 October - 7 November 1990), on the basis of the work of the Intergovernmental Panel on Climate Change (IPCC) concluded that without actions to reduce emissions, global warming is predicted to reach 2 ° to 5 ° C over the next century, a rate of change unprecedented in the past 10 000 years. The warming is expected to be accompanied by a sea level rise of 65+35 cm by the end of the next century. There remain uncertainties in predictions, particularly in the eastern Basin. On the other hand, warmer sea surface temperatures both in the Mediterranean and in the North Atlantic could lead to increases in atmospheric moisture and thus precipitation.

Another main consequence of a warmer atmosphere is an accelerated rise of sea level, due to the melting of alpine and polar glaciers and to the thermal expansion of oceanic waters. Sea-level has been rising since the last glacial maximum (120 m rise in last 16 000 years at rates as rapid as 8 to 12 mm/year. In recent historical times, the rate has been 0,5 to 1,5 mm/yr. Analysis of tide gauge data, the principal source of evidence for detecting relatively short-term sea level trends, suggest the world-wise rise has been about 10-15 cm in the past 100 years.

Depending on the extent of oceanic thermal expansion and especially the behavior of the polar ice caps (Greenland and the western Antarctic ice shelf), conservative to moderate estimates of sea level rise range from 13-39 cm (by 2025) and 24-52 cm (by 2050) to 38-91 cm (by 2075). Future sea level rises have been estimated at the UNEP Meeting in Norwich, September 1987. The best estimate of change between 1985 and 2030 is 14-22 cm, the approximate rise of sea level over the past 100 years.

There will be a significant lag in sea level rise, however coupled with oceanic thermal inertia. For example, if greenhouse gas concentrations stopped increasing in the year 2030, warming would continue for many decades. Since the glacial melting and thermal expansion of the oceans would continue, so would sea level rise.

Superimposed on sea level rise will be the effect of local tectonic and sediment compaction. Vertical earth movements in the Mediterranean commonly occur at rate of 1-5 mm/year averaged over thousands of years, and 3-20 mm/year averaged over 15-20 years. Local subsidence can exceed 5 mm/yr. It follows that in the future the economic cost of protecting or abandoning structures or land of the Mediterranean coast will depend strongly upon the local land movement coupled with sea level rise. Where land is subsiding, the net relative change could be much more than the global eustatic rise of sea level, where land is rising, the relative change will be significantly reduced.

In view of the importance of this issue the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP) in co-operation with several intergovernmental and non-governmental organizations , launched, co-ordinated and financially supported a number of activities designed to contribute to an assessment of the potential impacts of climatic changes and to the identification of suitable policy options and response measures which may mitigate the negative consequences of the expected impacts.

As part of these efforts, Task Teams on the implications of climatic changes were established in 1987 for six regions covered by the regional seas programme (Mediterranean Wider Caribbean, South Pacific, East Asian Seas and South East Pacific regions) with the initial objective of preparing reviews of expected climatic changes on coastal and marine ecosystems, as well as on the socio-economic structures and activities within their respective regions. Three additional Task Teams were established later, two in 1989 (for the West and Central African region and for the East African region) and one in 1990 (for the Kuwait Action Plan region).

In the framework of the activities of the Mediterranean Task Team six site specific case studies were prepared (deltas of the rivers Ebro, Rhone, Po and Nile, and for Thermaikos Gulf and Ichkene/Bizerte lakes) in the period from 1987 to 1990.

Since 1990 second generation site specific case studies (Island of Rhodes; Kastela Bay; Syrian coast; Izmir Bay; Malta; Cres/Losinj islands) have been and are being developed.

1.2. Basic Facts About Cres/Losinj Islands

The Cres-Losinj archipelago consists of two medium-sized and several small islands, which display a variety of the features typical of Mediterranean, limestone and sandy islands.

As a consequence, the results of this study should be of considerable interest for the whole Mediterranean community, while at the same time being of importance to the local island inhabitants, for future sound environmental management and planning.

The ecosystems of these islands are very complex and vulnerable entities of inter-related species, where every aspect of climate change and sea level rise will cause a wide range of environmental impacts.

The selected Cres-Losinj archipelago is the greatest island group in the Adriatic region.

Diversity of relief, climate, vegetation, landscape, flora and fauna on the relatively small area distinguish this archipelago from the others making it more interesting and specific.

The islands of Cres and Losinj are connected by a bridge over the narrow strait of Osor which separates them. Together with a group of smaller islands near-by (Unije, Male and Vele Srakane, Susak, Ilovik) these islands make up the western part of the Kvarner Island Group. The great variety of landscapes, vegetation and soils (mostly karst but also fertile land on sand), together with their extremely attractive coastlines and such unique features as the Vrana lake (a fresh water source below sea level), makes these islands important tourist areas. The environmental conditions are representative of all the typical and specific landscapes found on the Adriatic islands.

The archipelago includes the islands of Cres (404.3 km^2) and Losinj (74.7 km^2), Unije (16.8 km^2), Male and Vele Srakane (2 km^2), Susak (3.7 km^2), Ilovik (5.9 km^2), Zeca (2.9 km^2), and Sv. Petar (0.9 km^2):

- inhabited as early as the Bronze Age; the ancient Greek ports of Cres and Osor (the place of junction of the Islands of Cres and Losinj) existed, were later used as merchant ports for the amber trade;

- the islands are reached by sea with ferry-boat connections at two places (approximately 5.5 km) and a shipping line from Rijeka (the regional centre -26 km);

- climate: moderate and with low diurnal and seasonal variation; low precipitation in summer; daily average of 10 sunshine hours; prevailing winds are the "Bora" (NE) and the "Jugo" or "Sirocco" (SE);

- the highest peaks of relief are Sis (638 m) on the island of Cres and Osorcica (588 m) on the island of Losinj;

- vegetation: great landscape variety, ranging from the bare karst terrain and the maquis vegetation of Cres, to the Mediterranean pine woods of Losinj and with individual, specific environmental units, such as a the sandy island of Susak with many vineyards;

- on the island of Cres the share of the forest area is 33% and the share of pastures is 45% within the total surface area. On the island of Losinj the share of forest area is 40%, being very similar on the islands of Ilovik and Unije;

- the only fresh water resource is the Lake of Vrana with a surface area of 575 hectares - 10 m above sea level, maximum depth 75 m, which is 65 m below sea level;

- there are 39 settlements and 11,639 inhabitants on the islands; the total number of tourist beds is 36,044, while the annual number of tourists is 328,000.

1.3. Methodology and Assumption Used in the Study

The work on this study was organized in the way to achieve results and findings which could serve for future physical planning documentation, while at the some time being a model for the Adriatic and Mediterranean islands.

Multi-disciplinary Task Team was composed of experts dealing with their substantive section for a long period of time thus being very well informed about the subject.

Wherever it was possible the local representatives, living and working at the islands, were included and from the very beginning a successful contact was established and considerable interest was induced by local government. Therefore, it is expected that it will be guarantee for accepting the results of the study as well as for their timely applying and using.

The existing documentation was the basis for the study, paying special attention to the identifying of possible implications of expected climatic changes.

Out of the framework of the study programme the empirical research (questionnaire) was carried out in June 1992, in order to find out the attitude of islands population concerning the climatic changes and their possible manifestations.

During the working period the close co-operation was established both among the authors of substantive sections and among them and co-ordinator of the project.

A few meetings with the participation of all the members of Task Team were held and the two of them with the presence of external experts of UNEP.

For the specific purpose of the study a sea level rise of 24-52 cm and a temperature elevation of 1.5 to 3 degrees Centigrade by the year 2050 will be used, taking into account:

- the best available information, knowledge and insights into the problems relevant to the Island Group area including major projects, planned or under consideration;
- the assumptions accepted at the Second World Climate Conference (1990), ie an increased temperature of 2-5 °C and sea level rise of 65+35 cm before the end of the 21st Century;
- the IPCC statement concerning potential changes to the climate of Southern Europe (35 °-50 °N 10 °W - 45 °E) that: "warming would be about 2 °C in winter and would vary from 2 ° to 3 °C in summer. There is some indication of increased precipitation in winter but summer precipitation decreases by 5 to 15%, and summer soil moisture by 15 to 25%.";
- the expected results of the University of East Anglia's Scenario analysis for the Mediterranean Basin with sub-regionally specific scenarios.

2. IDENTIFICATION AND ASSESSMENT OF THE POSSIBLE CONSEQUENCES OF CLIMATIC CHANGE

2.1 Climatic conditions on Cres-Losinj Islands

2.1.1 Introduction

In the recent time there is an arising interest of the scientific as well as of the public opinion (including also state authorities) for climatic changes on the Earth, especially pointed to by observations of the last several decades. Namely, global surface temperature has risen about 0.5 C degrees Celsius on the Earth, compared to that of some hundred years ago (Sijerkovic I Pandzic, 1991). The question is made if that is an usual climatic fluctuation or it is a consequence of human acting by atmospheric pollution produced by industrial development. The theory is showing that some gases (carbon dioxide, methane and others), released into the atmosphere by fossil fuel burning, are transmitting shortwave Solar radiation, but not also the long wave terrestic radiation. On this way they retain a part of the Sun energy in the system Earth - atmosphere what can cause a temperature rise on the Earth. This effects is called "greenhouse effect" and the gases causing it are called "greenhouse gases". If the other climatic factors, which at least partially (e.g. an increase in cloudiness) compensate that influence, are neglected, a rise of the global temperature on the Earth as a function of the greenhouse gases concentration rise can be estimated. So most climate models anticipate a temperature rise of several degrees Celsius during the next century supposing carbon dioxide (CO) concentration in the atmosphere to double. As the consequence of Earth warming also the sea level rise for several tens of centimeters in the next hundred or so years is anticipated. The cause for this is thermic expansion of oceans and melting of polar ice caps (UNEP, 1992).

The mentioned temperature changes may also cause changes in other climatic elements like air atmospheric pressure, precipitation, sunshine, wind and others. Further, these changes will not have the same intensity during the whole year, so they are depending on the season. To be able to mitigate or possibly positively use the anticipated global climatic changes it is necessary to reduce their effects to the local level. To make possible considering future state of climatic conditions in a better way the current state of the climatic conditions on the Cres-Losinj islands will be present.

2.1.2 Present Climatic Conditions and their Trend

Because the atmospheric pressure, air temperature and precipitation are mostly considered in context of climatic changes most space will be dedicated to them. However, the wind, sunshine, global radiation and cloudiness characteristics will be presented. A very short consideration will be given to the snow cover because it is very rare phenomenon over the area considered. Similarly it is with fog and frosts which are also not frequent on Cres-Losinj islands. Fog appears in average once on month in the winter half-year, and mostly it does not appear during the summer over the whole area. However, frosts are considerably a more frequent phenomenon during the winter over the northern part of the islands (in average up to seven times in a month) and on the southern part much rare - up to twice in a month. Also the water balance components, including the moisture content in soil, partially belong to the climatic conditions, but due to the fact that they will be discussed in the chapters "hydrosphere" and "lithosphere" they will be avoided here. By the Pandzic's (1985) results it can be stated that on the whole eastern Adriatic coast and so consecutively on the examined islands all water balance components have an expressed seasonal character because they are primarily a function of temperature and precipitation (seasonal wind change is disregarded). So evaporation (or evapotranspiration) has its maximum in summer and its minimum in winter, while the moisture content in soil has an inverse annual cycle related to it.

The results are mostly related to data from the period 1961- 1990 with exception of the trend for which time series from the period 1891-1990 were used. A special stress is given to the seasons as the results of the climatic scenario are related to them. It will be discussed climatic extremes although, until now they are mainly not considered in climatic models.

2.1.3 Atmospheric pressure

One of the more important generator of the atmospheric circulation is also atmospheric pressure distribution, by the SI system is expressed in hectopascals (hPa). Centers of lower atmospheric pressure are called cyclones (or lows) and those with higher anti-cyclone (or highs). Pressure differences in these centers and their environment cause occurrence of pressure gradient force which, balanced by Coriolis force (inertial force of the Earth's rotation), supports circular air streaming (wind) and thus in a low counterclockwise and in a high clockwise. Therefore if standing with the wind blowing to our back, then the center of lower pressure is about to the left (Buyes-Ballot's rule). Some deviations appear due to the friction influence.

The atmospheric pressure distribution changes from year to year. In Figure 2.1.1a (a') it may be seen that the atmospheric pressure during the winter (January) is lower over the Northern Atlantic (Icelandic low) and higher over the European land. During the summer (July) it is reversed, the pressure over Atlantic is higher (Azores high) and lower over the land. It is a consequence of difference in warming rate of sea and land. Namely, land is warmed up faster than sea and it is warmer in the summer, but it cools off faster too, so it is cooler than sea in the winter. Related to it the distribution of lows centers is also different (Figure 2.1.1 b(b')) in the winter than in the summer. There are more of them in Mediterranean in the winter than in the summer. Most highs are distributed over the land during the winter (Figure 2.1.1c) and over Atlantic during the summer (Figure 2.1.1c'). Areas of low and high pressure in multi-annual average take designation of centers of action. The designation is justified because, as evident from the illustration, they mostly coincide with areas of high frequency of cyclones and anticyclones.

From the presented it may be concluded that the Cres-Losinj area during the winter half year is more influenced by patterns of lows and during the summer by highs. It has a great influence on the annual precipitation pattern as well as on the wind pattern what about will be still more said later. Of course each change in the existing circulation pattern has a significant influence on the pattern change of mentioned elements.

2.1.4 Temperature

As the temperature is a quantitative indicator of the thermal stations of the atmosphere, i.e. a measure for thermal energy, which is agitator of all processes on the Earth, it usually merits most attention. It changes in space as well as in time. Generally, it is warmer in lower latitudes and during the summer and colder in higher latitudes and during the winter.It has also diurnal course so its maximum falls slightly after noon and its minimum after midnight.

Temperature pattern depends on the kind of the ground. So areas exposed toward sea have a milder (maritime) climate with less temperature variations during a day or a year, and areas deeper in the land have a more severe (continental) climate with more pronounced daily and seasonal variations. This depends also on orographic characteristics, prevailing air streams, exposition toward the Sun and many other microclimatic influences.

Because on Cres-Losinj islands there are continuous air temperature measurements only at two towns: Mali Losinj and Cres, they were taken as representant for the whole considered area.The results of statistical analysis for these two places are presented in Table 2.1.1. Looking at the Table it can be seen that at M. Losinj, consequently at the southern part of the archipelago, it is, in average, for 1 C warmer than at the northern (at town Cres).However, it is not case for all seasons. Namely, in summer it is, in average, warmer at some northern parts of islands than at the southern (the case of the relation between M. Losinj and the town Cres). It is sure a consequence of a stronger sea influence on the southern and of the surrounding land at the northern part of the islands. To it shows also a smaller range of extremes at M. Losinj and Cres. All of this contributes to still greater comfort of climate in southern parts of islands, although the differences are not significant, compared to some parts on the north.

There are also some peculiarities in temperature conditions on tops of islands. If temperature decrease with elevation of 0.5 C per 100 meters is supposed, then distribution of mean annual temperatures can be presented by isolines (Figure 2.1.2).From the presentation may be seen that the differences between coastal and top island zones do not exceed several degrees.

Table 2.1.1 Temperature Regime Characteristics for:

	Winter	Spring	Summer	Autumn	Year
a) M. Losinj					
Average (°C)	8.1	13.3	22.7	16.3	15.1
Seasonal Max (°C)	11.4	14.7	23.7	17.9	15.9
Return period (year)	>100	27	22	27	>100
Seasonal Min (°C)	6.7	11.5	21.8	14.6	14.4
Return period (year)	17	43	17	56	34
Daily Max (°C)	20.4	28.8	35.2	31.7	
Return period (year)	176	19	32	34	
Daily Min (°C)	-6.7	-3.8	9.7	1.3	
Return period (year)	74	36	45	21	
b) Cres					
Average (°C)	6.6	12.9	22.6	15.0	14.3
Seasonal Max (°C)	8.4	14.6	24.5	16.7	15.2
Return period (year)	56	>100	>100	>100	43
Seasonal Min (°C)	3.4	11.0	21.4	11.6	13.5
Return period (year)	>100	91	16	>100	43
Daily Max (°C)	20.7	30.1	37.4	32.8	
Return period (year)	50	17	28	15	
Daily Min (°C)	-9.2	-6.5	7.8	-3.4	
Return period (year)	47	25	17	27	

To research what happened to the temperature during the last some hundred years. The trend analysis has been made, based on climatological data for Crikvenica (not far from Cres-Losinj islands) from the period 1891-1990. The results, presented in Figure 2.1.3 indicates a slighter rise of mean annual temperature (0.34 C per 100 years) over this area. However this warming is mostly expressed during the fall (0.70 C per 100 years) and slighter during the summer (0.25 C per 100 years). Spring temperature has meanwhile a negative trend (- 0.21 C per 100 years).However the mentioned change are not statistically significant.A monitoring of year temperature trend can indicate such a change which is expected in the next period.Similar results achieved also by Maheras (1989) who used more time series of temperature from the Western Mediterranean area. He concluded that the climate of this area in the last period takes more and more characteristics of the Atlantic climate with relative mild winters and fresh summers.

2.1.5 Precipitation

In contrast to temperature which mainly depends on the length and intensity of the Sunshine, precipitation primarily depends on the type of the air circulation and moisture content in it. So, in cyclonic circulation type appears a vertical rising of the air and its cooling where water vapour condensation, clouds and precipitation formation take place. With anticyclonic streaming type sinking of the air and its warming up take place,where the clouds disappear and clearing takes up. Besides of circulation,orographic influence is essential for forming precipitation. So,during Sirocco on the Eastern Adriatic coast, the process of generation (air rising)intensifies and during Bora(air sinking) a dissolving process of clouds and precipitation exists.Precipitation is also supported by frontal zones (boundaries between cold and warm air masses) as well as by local instabilities caused by stronger warming of the ground layers of the atmosphere in relation to upper ones. Result of this process is so called convective precipitation.

Of course all of these influences commonly form precipitation pattern Cres-Losinj islands. After all a cyclonic activity influence and orographic effects are prevailing. The first is reflected on the annual pattern and the second on the space distribution (Table 2.1.2 and Figure 2.1.4). As it is evident from the Table 2 greater amounts of precipitation are during the winter half year (autumn, winter) than in summer (spring, summer). It is related to the frequency of passages of lows over this area (Figure 2.1.1b(b') and Pandzic, 1988). From Figure 4, but also based on the mentioned Table 2 a rise in precipitation toward north of the islands is evident. This is, in major part a consequence of the orographic effect not only of the island alone but also of the Quarner hinterland. Namely, funneled form of the Rijeka's Gulf causes a rising of the air, usually more moist, brought by southerly wind, not rarely related to cyclonic systems. Therefore, the Quarner hinterland has the most precipitation in Croatia, more than 3500 mm per a year in average what is rarity even in Europe (Crkvice in Boka Kotorska have the greatest annual precipitation in Europe of 5000 mm).

Table 2.1.2 Precipitation Regime Characteristics for:

	Winter	Spring	Summer	Autumn	Year
a) M. Losinj					
Mean (mm)	259	198	165	313	933
Seasonal Max (mm)	514	291	284	658	1368
Return period (year)	>100	20	20	>100	43
Seasonal Min (mm)	67	78	67	73	580
Return period (year)	90	>100	25	90	>100
Daily Max (mm)	58.4	66.0	83.4	156.9	
Return period (year)	21	77	31	240	
b) Cres					
Mean(mm)	299	234	198	339	1063
Seasonal Max (mm)	612	400	430	573	1419
Return period (year)	56	>100	91	25	22
Seasonal Min (mm)	59	109	61	124	734
Return period (year)	>100	91	43	43	24
Daily Max (mm)	87.2	68.1	113.4	104.3	
Return period (year)	93	34	52	53	

The analysis of changes in annual precipitation amounts was made using the data of nearby Crikvenica for the period 1891-1990.As in the annual as well as in the seasonal series there is a decrease in precipitation (Figure 2.1.5). The main contribution to the decrease of the annual precipitation amounts gives decreasing of fall and summer amounts. In total it is 1.62 millimeters per year of which 0.17 during the winter, 0.30 during the spring, 0.46 during the summer and 0.68 during the autumn. Thus,the annual precipitation decreasing tendency in relation to the multi-annual average 0.13 percents, in summer 0.19, in autumn 0.15,in spring 0.11 and in winter only 0.06 percents. However, statistical tests are showing that this trend is still not significant. Also,continuous monitoring of the precipitation trend may signalize possible more essential changes in precipitation amount in this area.Some aspect of the time variation in precipitation for a larger space (over Balkan) were observed by Maheras (1990).

There is no much sense for explication on solid precipitation on the islands themselves because they are relatively rare. If the last 30-year period is taken into consideration, only in a few years snow on the ground was recorded in the area. The highest was recorded in 1962 with a height of 13 centimeters at town M. Losinj with duration of 9 days.

2.1.6 Wind

If there was no wind the climate on the Earth would be far unfavorable for life. Namely, owing to the air stream an exchange of thermal energy between zones in lower and higher latitudes is performed and so temperature difference between them is being relieved. The wind also brings water vapor, clouds and precipitation from apart oceanic spaces to the land. It pollinates, refreshes coastal areas during the summer heat etc. However, it has also negative effects: it increases feeling of cold in winter days,if it is strong destroys buildings, breaks trees, interferes with traffic etc.

For Cres-Losinj area seasonal winds are characteristic: Bora, Sirocco and so called coastal circulation. The first two are more related to the winter and the last to the summer part of the year. Otherwise Bora is a relatively cold, strong and gusty wind blowing from the northeastern quadrant, perpendicularly to the coast bringing weather improvement. Sirocco is a kind of the antipode to the Bora. It is relatively warm and steady wind from southeastern quadrant, parallel to the coast and it brings weather deterioration and it generates big waves on the sea. Coastal circulation is related to days with fine and on the broader scale calm weather. It is caused by uneven warming (cooling) of land and sea. In the night the land is colder than the sea and the circulation is directed toward sea ("Burin"), as during the day the sea is colder than the land a refreshing wind("Maestro")blows toward land (Luksic, 1989). Relative annual frequencies of Bora and Sirocco are presented in Table 2.1.3 (Makjanic, 1978).

Table 2.1.3 Relative number of terms with Bora and Sirocco at town M. Losing

	Bora		Sirocco	
Station	Winter	Summer	Winter	Summer
Mali Losinj	74 %	26 %	74 %	26 %

As the matter of course besides of seasonable variability also a space wind variability exists as by its direction so by its force. This is illustrated by annual wind roses presented in Figure 2.1.6. It is evident from the drawing that at M. Losinj the frequency of strong Bora is less than at nearby town Senj (Luksic,1975),but there is more stronger Sirocco at M. Losinj than at Senj. However, over the whole Quarner the wind from northeastern quadrant is prevailing (Bora).

Maximum gusts of Bora and Sirocco can exceed 100km/hour (Bajic, 1989). However, generally, the frequency of strong Bora decreases moving from the north of Adriatic toward south,as for Sirocco the reverse is valid. Areas with stronger wind are potential, alternative and ecological pure energy sources. As the wind in a substantial measure depends on atmospheric pressure distribution, each change in its distribution will cause change in wind pattern and by it also in sea waves as well as in sea streams.

2.1.7 Cloudiness, sunshine and global radiation

Because these three elements have a big influence on the energy state of the Earth-atmosphere system they are physically even more important than the formerly described. However, such arrangement of their description was made because the earlier explained elements, especially temperature and precipitation, were discussed with more stress from the aspect of climatic change, especially if it was dealt with a local scale.

Cloudiness plays an important role in creating precipitation pattern, radiation balance and it has also an important influence on air traffic. The results presented in Table 2.1.4 show that (in average) cloudiness (expressed in tents of the sky) is the most in winter and the least in summer months. The number of clear days (cloudiness < 2/10) is greatest in summer and cloudy days (cloudiness > 8/10) reverse is valid.

Sunshine or periods with the Sun shining (expressed in hours) in a way is complementary to the cloudiness. For the Cres-Losinj island area it is of interest from the tourist aspect. Maximum number of sunshine hours comes up in the summer and minimum in the winter (Table 2.1.4). The space comparison for the broader Cres-Losinj area may be achieved by analyzing Figure 2.1.7. According to this picture the Sun shines about 200 hours per year longer at M. Losinj than in the nearby Pula or Rijeka (Pojeetal.,1984). It without doubt contributes to the tourism development on these islands.

Table 2.1.4 Cloudiness (tenths), Number of Cloudless and Cloudy Days, Sunshine (hours), Relative Sunshine (percents) and Global Radiation (kWh/m)

a) M. Losinj

Month	J	F	M	A	M	J	J	A	S	O	N	D	god.
Cloudiness	6	6	5	5	5	4	3	3	4	5	6	6	5
Clear days	6	6	8	8	8	9	16	16	12	9	4	5	107
Cloudy days	12	9	10	7	6	3	1	2	4	7	12	13	85
Sunshine	110	125	168	224	281	314	360	326	245	199	105	79	2540
Rel. sunsh.	37	45	46	53	61	65	75	73	63	58	39	34	56
Glob. radi.	1.3	2.0	3.4	5.0	6.2	6.4	6.6	5.8	4.7	3.2	1.7	1.0	47.1

b) Cres

Month													
Cloudiness	6	6	6	5	5	4	3	3	4	4	6	6	5
Clear days	7	7	8	8	9	9	16	16	14	10	6	5	116
Cloudy days	11	10	10	7	6	4	3	2	4	7	12	14	90

Global radiation has an important role in radiation balance. As it is related to the sunshine and to the Sun elevation respectively, it is not difficult to conclude that the maximum amounts are achieved in the summer and the minimum in the winter (Table 2.1.4). On the global radiation depends usability of Solar energy collectors, which are put on the roofs of dwelling structures and so used as alternative energy sources. It has also its ecological importance because these energy sources do not pollute the environment and so contribute to diminishing greenhouse gases and by this way as well as wind indirectly can diminish intensity of the forecasted climate change.

The trend monitoring of three elements, especially on the global scale, has a weight too, because a small change in one of them can cause disturbances in the climate system and may intensify climate changes.

2.1.8 Climate Change Scenario

As the most powerful tool in contemporary weather forecasting numerical hydrodynamic models are used, based on the initial state of the atmosphere (primarily atmospheric pressure distribution) calculate development of this state for more days in advance (successfully up to five or six days). Analogously also, climate (average) state of the atmosphere may be simulated by numerical models. However, there special so called Global Circulation Models (GCM) are used, which take into account a larger number of parameters than "common" forecasting models (e.g. radiation, cloudiness, ice cover etc.). Into these models usually atmospheric components like water vapor, aerosols (solid particles), greenhouse gases (e.g. CO) are introduced. Greenhouse gases, as it was already said, directly are influencing on radiation balance of the Earth-atmosphere system and global temperature on Earth's surface respectively. If their contents is greater, so the temperature is also higher. Consequently, if a larger percentage of these gases is introduced into the mentioned model it has to expected a rise of global temperature. However, this rise will not be the same in all points of the Earth's globe. Therefore additional analyses of so obtained results are necessary. Further, the temperature change will causes a change in atmospheric circulation and thus also in cloud amount, wind and precipitation distribution. Available results, however, are limited only to the temperature and precipitation field. Only in short, the atmospheric pressure was discussed.

The results of the GMC refer to the 4 X 5 grid points. Thus, they represent areas of several hundreds of kilometers. Because of that, it is not possible a detailed analysis by that results on a local scale, especially in areas of complex orography. This can be avoided using a conversion of the macroscale results to a local one. To establish a relation between these scales historical climate data and regression method were used. Final results were expressed in terms of global change temperature.

2.1.9 Air Pressure Scenario

Contrary to the temperature and precipitation, influencing by local conditions, it is not case by pressure. Therefore, the pressure results refer only to the broader Mediterranean area without sub-regional ones. They indicate a pressure decrease of 0.3 hPa per degree of global warming, what is not significant change. On the basis of that it is difficult to say something about changing present atmospheric circulation.

2.1.10 Temperature and Precipitation Scenarios

By application of the method described and GCM results, expected changes of temperature and precipitation for Northern Adriatic area have been obtained (Palutikof et al., 1992). Corresponding temperature and precipitation ranges for three time horizons: 2030, 2050 and 2100 and two locations: M. Losinj and Cres are presented in Table 2.1.5 for years and seasons separately.

a) Annual scenario

According to the cited table, an increase of temperature from 1-5 °C can be expected over Cres-Losinj area, depending on the time horizons. If real values of present mean annual temperature of 15 °C (in area considered) would be taken into consideration, then there is a probability for increasing mean annual temperature up to 20 °C. It can be alarming. However, a significant change of the annual precipitation is not expected. Namely, border of the zero change intersects the archipelago considered. Therefore, according to the model results, an increase and decrease of the annual precipitation could be expected on the northern and southern part of the islands, respectively. Thus, as average annual precipitation for the area ranges from 900-1500 mm, it is not difficult to calculate what changes could be for particular time horizon.

Table 2.1.5 Scenario of the Climatic Change for Cres-Losinj Islands

	TIME HORIZON 2030	2050	2100
M. LOSINJ			
TEMPERATURE:			
Annual	+1.6 do +1.8 °C	+1.4 do +2.8 °C	+1.8 do +5.0 °C
Winter	+1.4 do +1.8	+1.2 do +3.0	+1.6 do +5.0
Spring	+1.8 do +2.0	+1.5 do +3.3	+2.0 do +5.5
Summer	+1.8 do +2.0	+1.5 do +3.3	+2.0 do +5.5
Autumn	+1.8 do +2.0	+1.5 do +3.3	+2.0 do +5.5
PRECIPITATION:			
Annual	0 do -5 %	0 do -9 %	0 do -15 %
Winter	+ 5 do +10	+4 do +18	+6 do +30
Spring	- 2 do +7	-2 do +12	-2 do +20
Summer	- 7 do -13	-6 do -21	-8 do -35
Autumn	0 do +7	0 do +12	0 do +20
CRES			
TEMPERATURE:			
Annual	+1.8 do +2.0 °C	+1.5 do 3.3 °C	+2.0 do +5.5 °C
Winter	+1.4 do +1.8	+1.2 do 3.0	+1.6 do +5.0
Spring	+1.8 do +2.0	+1.5 do 3.3	+2.0 do +5.5
Summer	+2.0 do +2.3	+1.7 do 3.9	+2.2 do +6.5
Autumn	+2.0 do +2.2	+1.7 do 1.8	+2.2 do +6.0
PRECIPITATION:			
Annual	0 do +5 %	0 do +9 %	0 do +15 %
Winter	+5 do +10	+5 do +18	+6 do +30
Spring	+14 do +18	+5 do +18	+6 do +30
Summer	-7 do -13	-12 do -30	-16 do -50
Autumn	0 do -13	0 do -21	0 do -35
SEA LEVEL:			
Annual	+18 +/- 12 cm	+38 +/- 14 cm	+65 +/- 35 cm

After University of East Anglia could be for particular time horizon.

b) Winter scenario (December, January, February)

Expected temperature increase for winter season is similar to annual one. If we take into consideration winter temperature average of about 8 °C then a maximum increase of temperature up to 13 °C can be expected, what is present spring average.

Expected precipitation increase ranges from 5-30% over the whole archipelago depending on time horizon. This increase can not have a great importance because present winter precipitation is also high. Only usefulness could be in an increase of water resources in the Vransko lake as evaporation is small during the winter.

c) Spring scenario (March, April, May)

Temperature change is near to the annual one. If it is summed with present spring mean (about 13 °C) then a picture about temperature conditions in the area can be obtained.

A something less increase of the precipitation (up to 20 %) can be expected on the southern part of the area and up to 30 % on the north of it. This could improve agricultural conditions in the area.

d) Summer scenario (June, July, August)

For the summer season the model again estimates a increase of temperature similar to the annual, up to 5 °C. A summing of this value to 30-years average of 23 °C, a high temperature of 28 °C will be obtained. In that case, mildness of the archipelago is in question.

Average summer precipitation is 200 mm. An additional decrease of 30 or, somewhere, up to 50 % could seriously destroy present hydrological conditions.

e) Autumn scenario (September, October, November)

Again, a temperature change does seriously not deviate from the annual. However, contrary to the summer case, when mildness of climate is in question, this autumn warming could prolong "summer" conditions and thus improve comfort by summer heat being destroyed.

At precipitation some discrepancy between the north (a decrease up to 35 %) and the south (an increase up to 20 %) can be observed. It could reduce differences between precipitation of these subregions.

2.1.11 Possibility of Extreme Change Prediction

As it was mentioned, there is relatively slight possibility for prediction of climatic extreme change on the area considered. However, some conclusions can be made comparing different weather governing during summer and winter. Namely, it is famous fact that weather during the summer has a subtropical characteristics over the Cres-Losinj archipelago (warm, appearing of precipitation showers, longer drought periods etc.). Thus, by global warming, a tendency toward summer weather can be expected. Further, a stronger temperature contrast between equator and pols can causes stronger winds during the first part of the warming period (before melting ice caps). However, later, i.e. after ice cap melting, a decrease of the wind intensity can be expected. This would be worth for global scale (e.g. the Northern hemisphere), but not necessarily for Cres-Losinj area because of specific local wind regime.

In connection with warming, a moving toward the north of tropical cyclone paths (typhoons) can be expected. Thus, a possibility of appearing of these rare but dangerous phenomena could not be excluded. They are also accompanied with destroyed wind, strong rainfall and great waves if they move over water surface. Thus, according to this, an increase of short-period precipitation extremes can be expected.

As it is word about warming, a rising of lower limit of extremes could be expected as, after melting ice caps on the pols, the "sources" of very cold air will disappear. However, it has to be expressed that these hypotheses discussed in this section are rather speculative and they has to be taken with reserve.

2.1.12 Conclusion

Over the Cres-Losinj archipelago a mild Mediterranean climate prevails, characterized by warm and rather dry summers and temperate and rainy winter seasons. Snowy precipitation are very rare phenomenon. Prevailing winds are Bora and Sirocco, especially in the winter season. During summers, a refreshing wind from the sea (Maestro) prevails. Number of sunshine and fair days is the highest during the summer what is favourable for the tourism in the area.

According to GCM results, it has to be expected a warming from 1-5 C over Cres-Losinj area, what depends on time horizon. A higher increase of temperature could be in the second half of the 21st century.

The results do not indicate any significant change of air surface pressure over Mediterranean area and also over the Cres-Losinj archipelago. However, a change of present atmospheric circulation can not be excluded. It has to be expected, because of global warming, the circulation tendency toward it from summer season.

A significant change of the annual precipitation is not very probable. However, for each season separately, a significant change of precipitation can be expected. A decrease of precipitation during summer and autumn as well an increase during winter and spring was established. Winter increasing and summer decreasing of precipitation can improve and destroy hydrological island conditions, respectively. A contrast between these season will be still stronger.

About the other climatic elements and extremes it is difficult to say something definitely, but it is sure that the temperature change will cause also their change. However, sign and intensity that changes it is not possible to determine without complex and perhaps prolonged research projects being coordinated on the world level. During that study, an use of reach climatological data basis as well as global circulation models should be used. In addition, the oceans as great accumulators of thermal energy should not be forgotten.

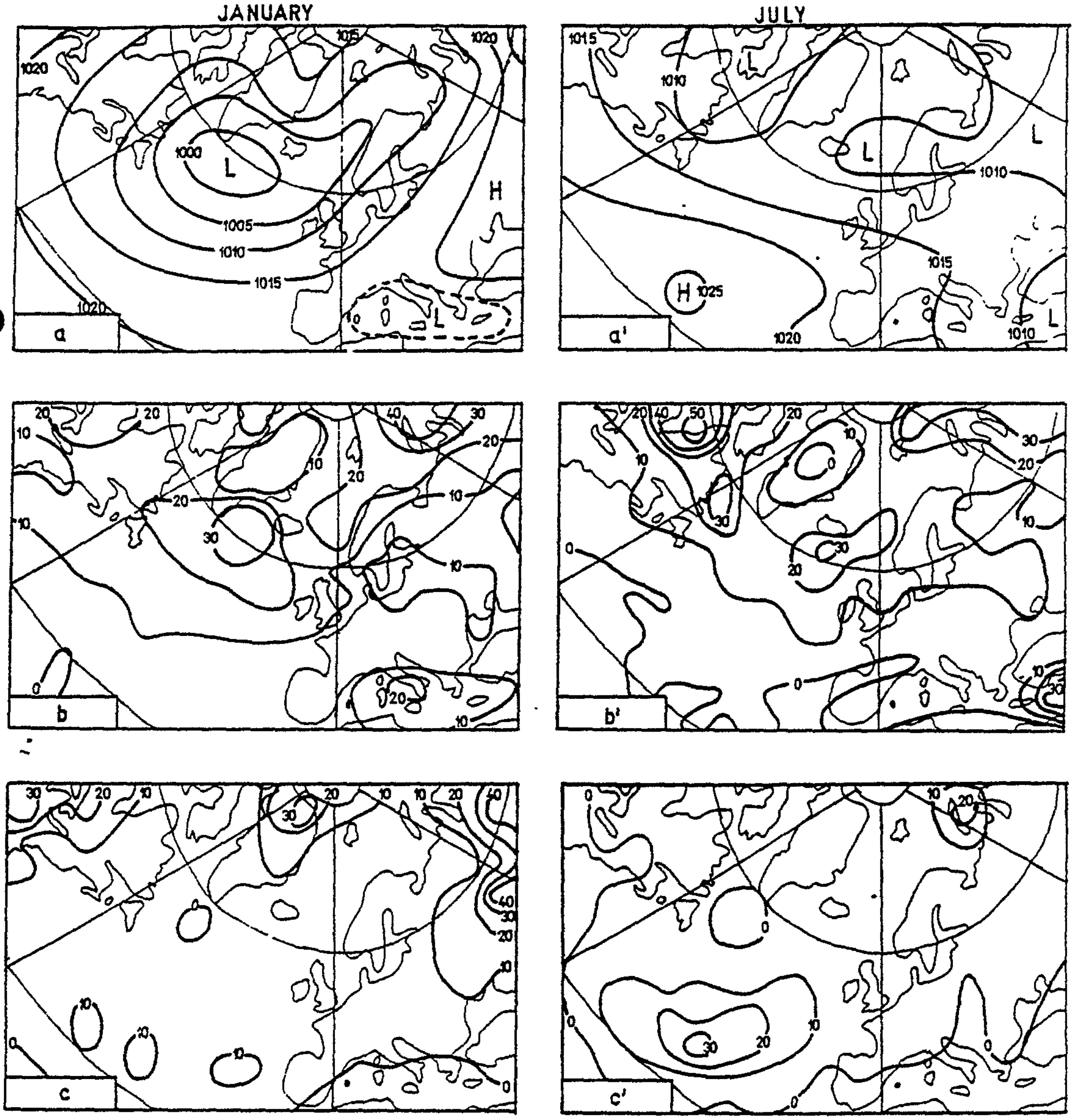


Figure 2.1.1 Centres of action in January and July denoted by: a,a') 20-year (1961 to 1980) mean monthly atmospheric pressure reduced to sea level, b,b') occurring frequency of lows, and c,c') occurring frequency of highs

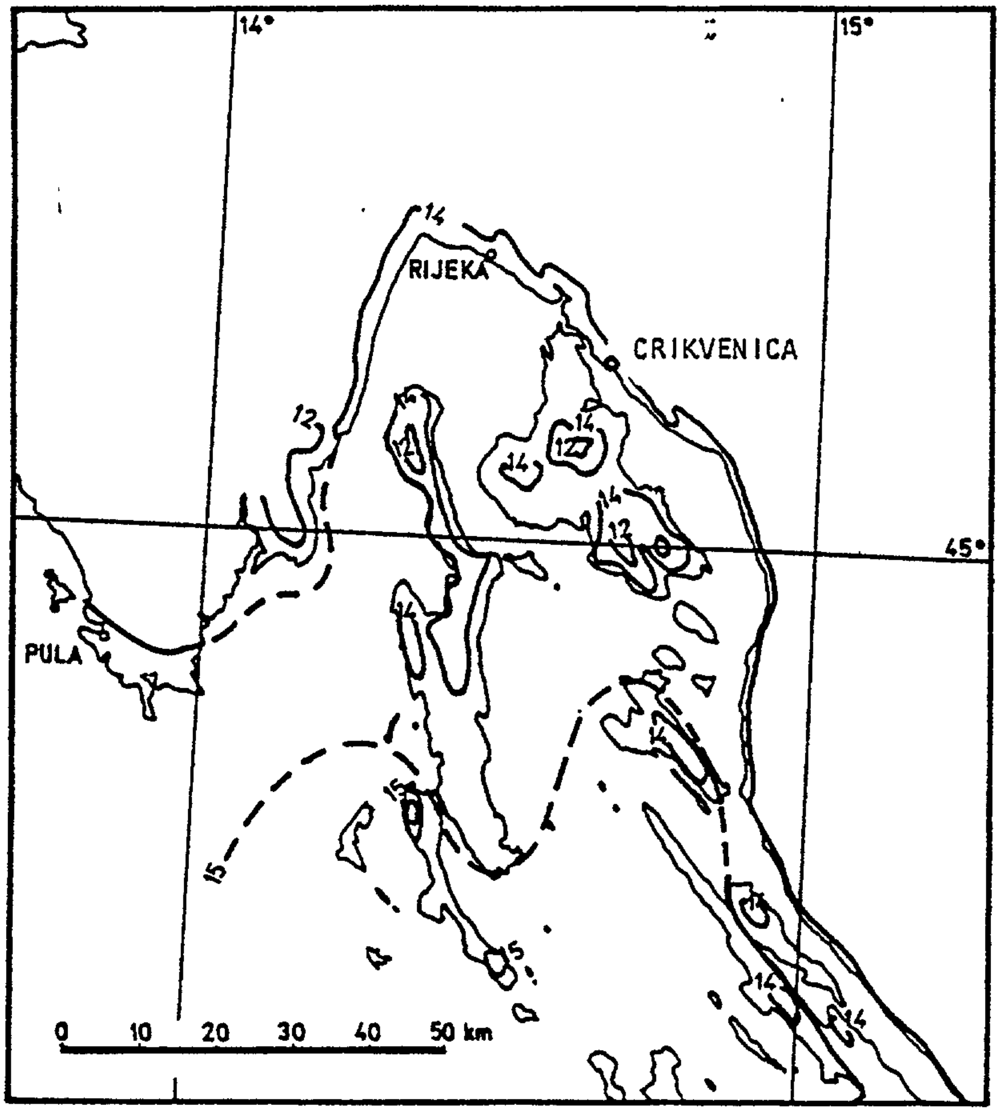


Figure 2.1.2 Mean annual temperature distribution for the extended Cres-Losinj Island area

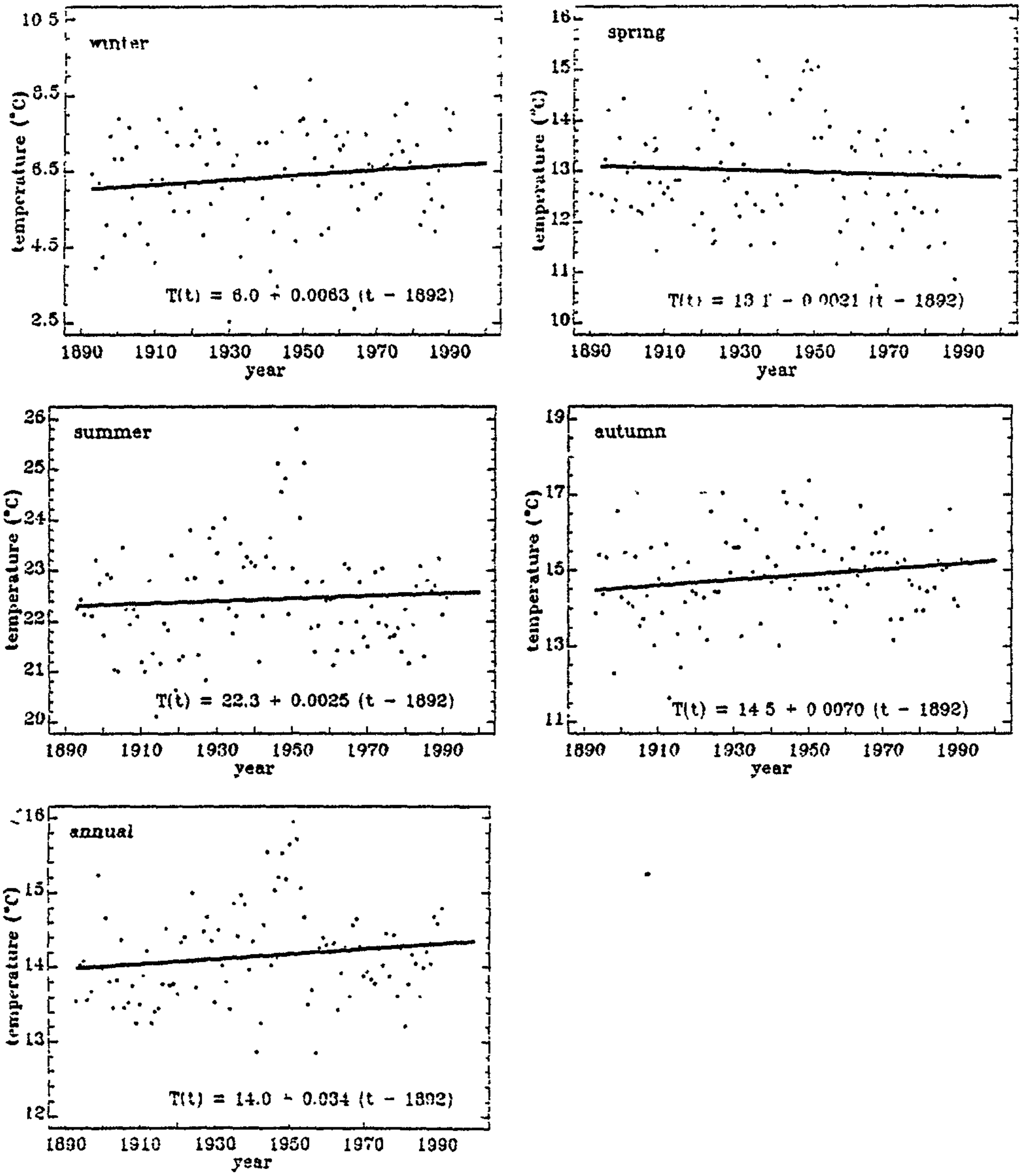


Figure 2.1.3 Time series of mean seasonal and annual temperatures with related trends for Crikvenica (1891-1990)

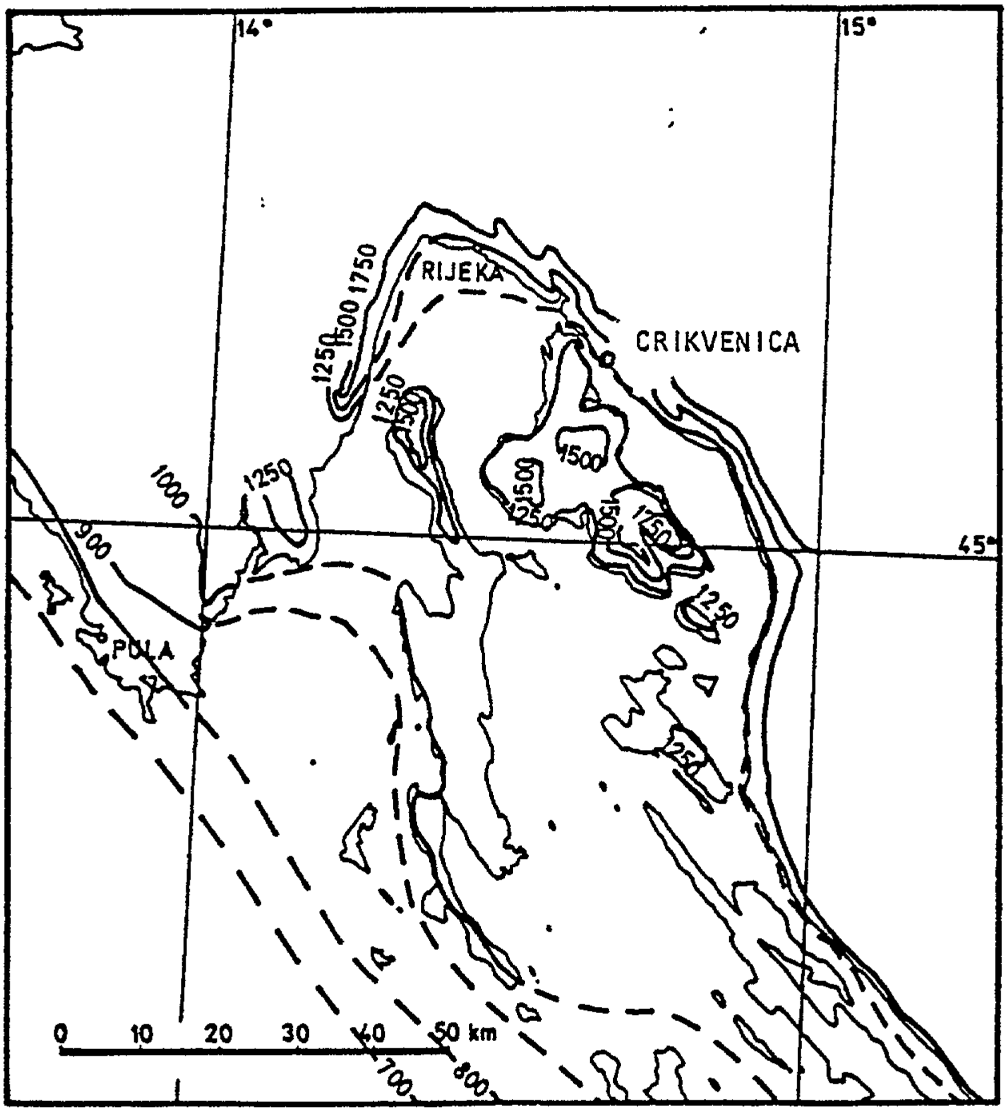


Fig.2.1.4. Mean annual precipitation amount distribution for the extended Cees-Lošinj island area

Figure 2.1.4 Mean annual precipitation amount distribution for the extended Cres-Losinj Island area

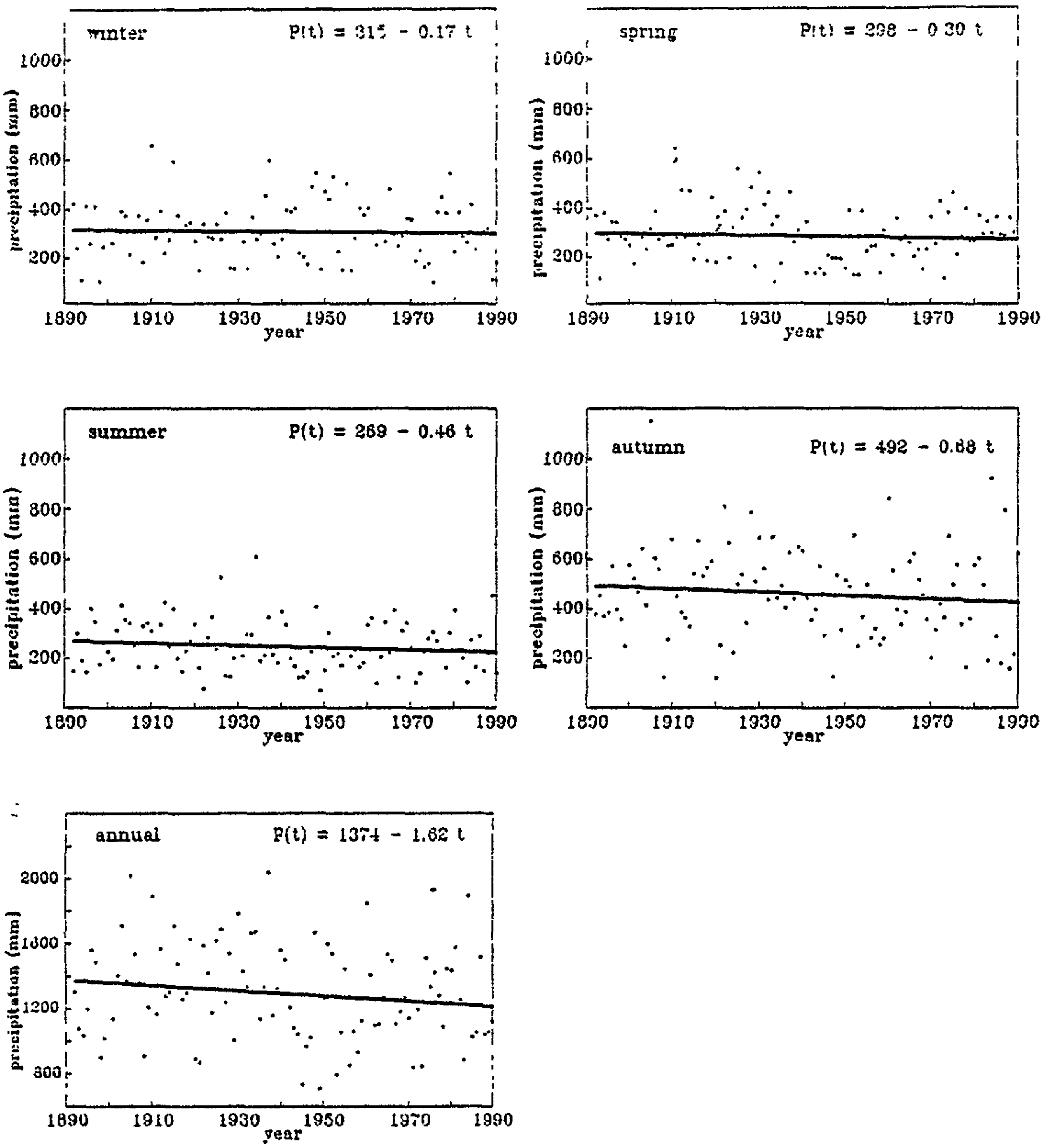


Figure 2.1.5 Time series of seasonal and annual precipitation with related trends for Crikvenica (1891-1990)

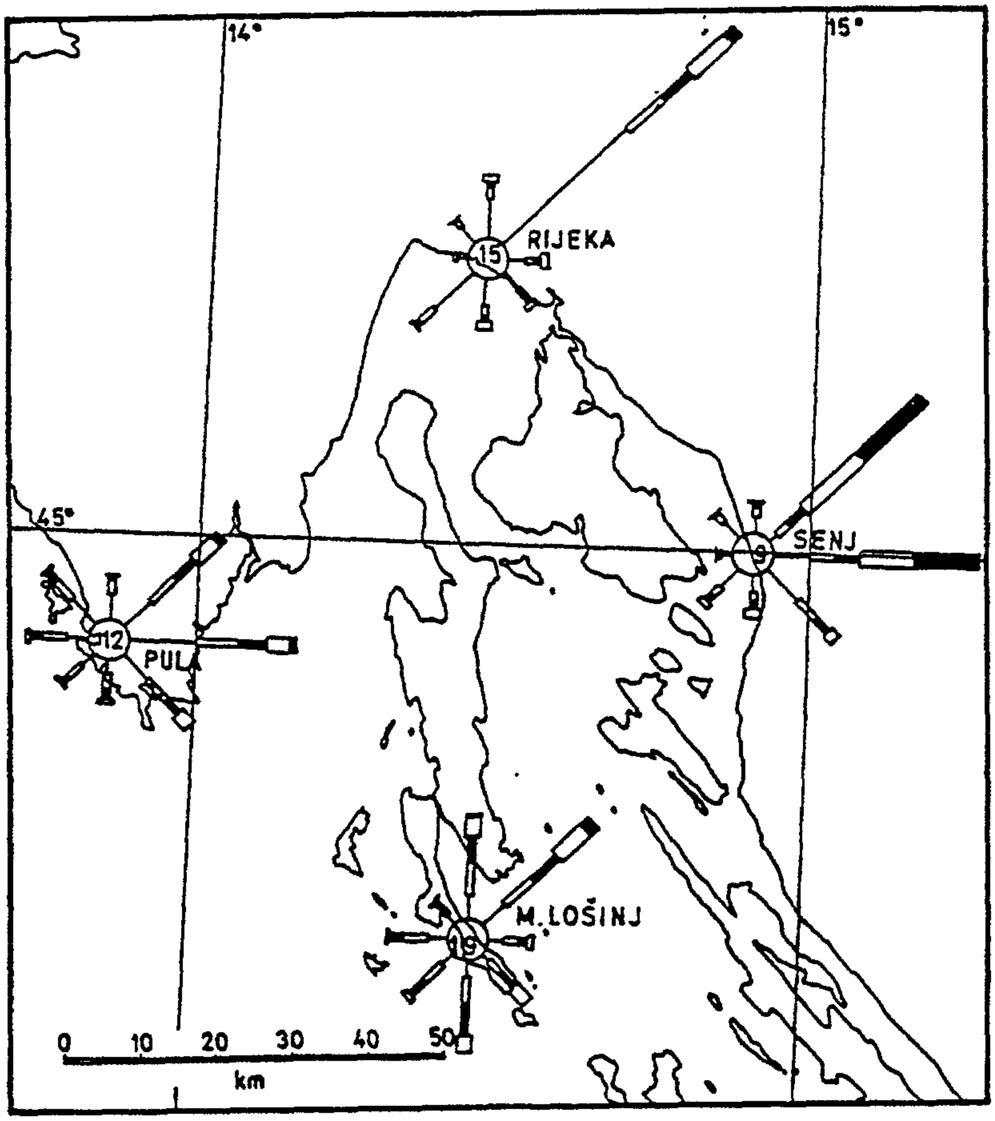


Figure 2.1.6 Wind roses for the extended Cres-Losinj Island area. Different widths and shadings in the histograms indicate different wind forces (in the centre there are percentages of calms, first elements depict one Beaufort, second of two, etc.)

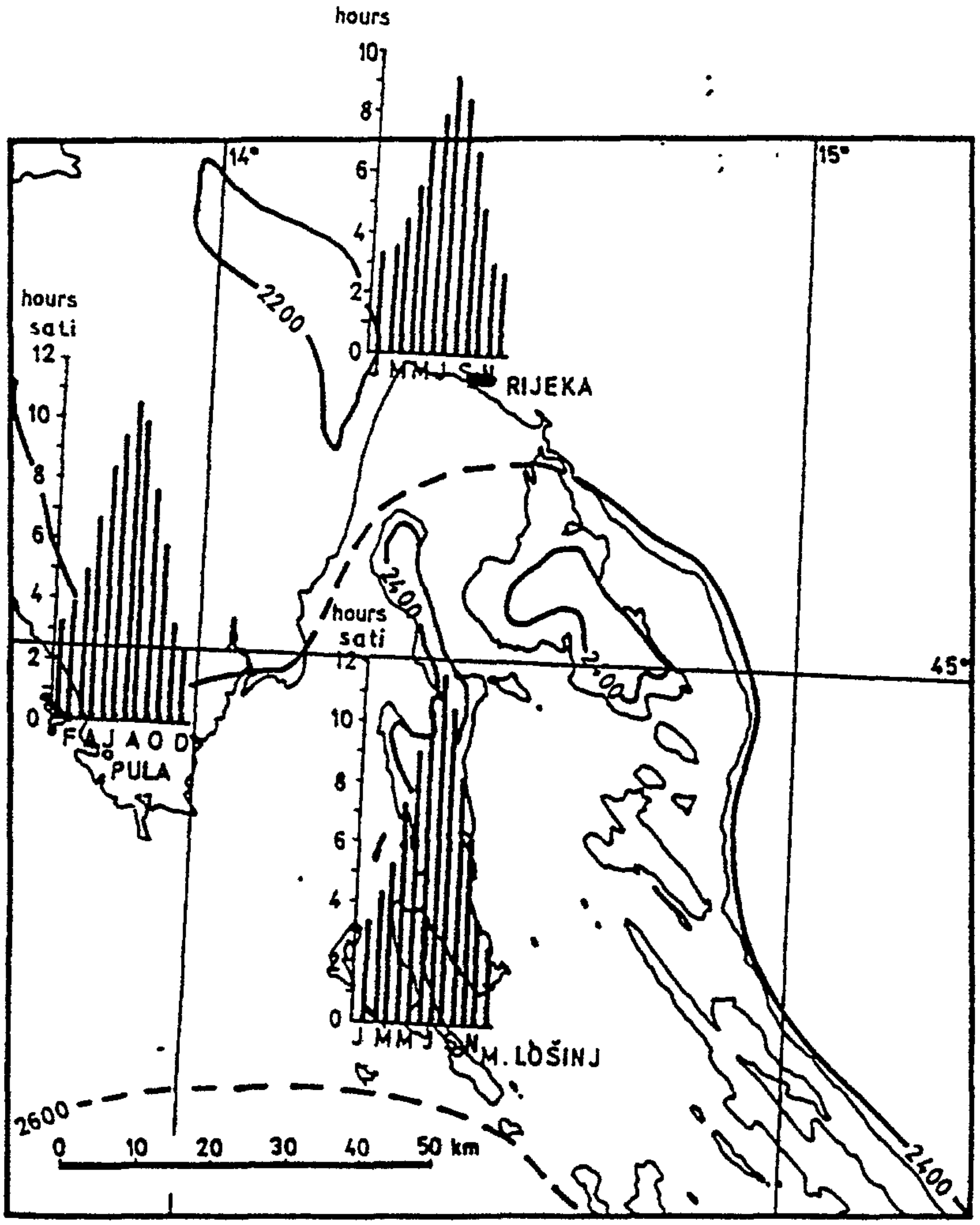


Figure 2.1.7 Annual sunshine regime for the extended Cres-Losinj Island area

2.2 Lithosphere

The lithosphere is a common term for the solid part of the earth, for its crust, with the maximal thickness reaching 100 km. Hence, when we speak about the consequences of global climatic changes of the lithosphere, in fact, we consider only the uppermost part of that lithosphere, almost its "surface", because only that part of the lithosphere occurs in the zone of climatic influence. However, within this chapter, it is necessary to explain also a global tectonic framework of the considered area in order to understand better the position and significance of that area within the Mediterranean region, for which this research project is being made.

The islands of Cres and Lošinj with associated small islands are composed mostly of karstified carbonate rocks and it makes the main lithological feature of the entire group of islands. The limestone/dolomite ration is mostly stabilized. The rocks alternate zonally, along the northwest-southeast direction that is also the trend of the islands and of the Dinaric structures. Within the Cres-Lošinj group of islands, the following seven lithostratigraphic units are separated and they are also typical for the Dinaric karst (the Adriatic platform):

K_1	- gray limestones with dolomite lenses - Lower Cretaceous
$K_{1,2}$	- dolomite, dolomitic breccias, dolomite and limestones in alternation - Lower to Upper Cretaceous
$K_2^{1,2}$	- rudist limestones - Upper Cretaceous
Pg_2^1	- foraminiferal limestones - Paleogene
Pg_2^2	- flysch deposits - Paleogene
Q_1	- eolian deposits - Quaternary
Q_2	- terra rossa - Quaternary

The Cretaceous and Paleogene rocks are a part of the Dinaridic basic structures and they have a characteristic zonal occurrence (Fig. 2.2.1.). The limestones and dolomite are mainly of Cretaceous age. By their petrographic features and habit, they fit into the regional relations of the Dinarides of the northern Adriatic space. The Upper Cretaceous rock complex builds the larger part of the islands and, in it, crystalline dolomite and limestones with rudist remnants prevail. Only some minor masses of limestones are of Paleogene age. They are foraminiferal limestones and their outcrops may be traced along obvious longitudinal reverse faults. The appearances of flysch deposits of Paleogene age (Eocene) are numerous, but of a considerably lesser superficial extension than those of the Cretaceous limestones and dolomite. They are noticeable clearly at the ground surface in the southwestern cost of the Cres island, between the villages of Lubenica and Martinšćica. However, during a thorough geological exploration, the occurrence of flysch deposits were noticed also within the Upper Cretaceous limestones. It may be explained only by a turbulent tectonic movements within that space. Lithologically, they are predominantly calcareous marls but, in some places, they are entirely clayey sediments with interlayers of sandstones. Geophysical explorations in the Lake of Vrana area showed the existence of rocks having low resistivity under carbonate rocks. This suggests about a far larger extension of flysch deposits in a deep underground of these islands than it is indicated by the superficial occurrences of these rocks. The sandy sediments of eolian origin and Quaternary age were recorded in the southwestern side of this group of islands towards the open Adriatic sea (the islands of Lošinj, Unije, Srakane, Susak). It is a semi-cemented sand blown by the wind from the Po river delta. Terra rossa are the youngest Quaternary deposits. They are formed by weathering of carbonate rocks and usually fill the dolines (sinkholes), depressions and poljes of the karst relief. There are no surface streams on the Cres-Lošinj group of islands. That is the reason why terra rossa occupies minor areas and has a small thickness, although it is very significant for the insular vegetation. Somewhat larger accumulations of terra rossa are associated with the zones composed of dolomitic rocks which are less resistant to weathering than limestones.

Tectogenetically, the Cres-Lošinj group of islands belongs to the Adriatic structural unit of the Dinarides (Herak 1986, 1992). Overthrust structures make the main feature. The Dugi Otok fault zone extends along the front of the Adriatic unit overthrust nappe. That zone continues on the Istria peninsula, into the Ćićaria fault zone. According to Aljinović (1984), the depth of the footwall plane of a sedimentary complex of rocks range between 3.5 and 6 km at the town of Cres area (Fig. 2.2.2). The rocks occurring under that level subduce beneath the Dinarides. Above that level, reverse structures and overthrust blocks were formed. Regional stresses, caused by tectonic movements deep underground, resulted with a rotation of the formed structures, as it happened to the Cres island itself (Anderson & Jackson 1987, Aljinović et al. 1987, Prelogović, 1989).

At reconstructing the formation of structures, most important step was to define several active zones, which have made the present structural relationship. First of all, it relates (1) to the tectonic movements that took place during the Younger Tertiary that resulted in the shifting and rotation of a wide structural complex accompanied with constant changes of the regional stress direction and (2) to a youngest tectonic phase which includes also the recent activity. The amplitude of neotectonic movements cannot be determined due to a lack of Quaternary "bench mark" deposits at the islands, however, some measured elements undoubtedly indicate the prevalence of horizontal movements. According to the geological map and cross sections (Fig. 2.2.1), three faults outstand - that of Lošinj, the Western Cres one and the fault passing between the Valun and Koromačno bays that has the Dinaric trend. They are basic reverse faults of the islands (of their overthrust) and they were intensively formed during the neotectonic activity. Longitudinal "relaxation" faults have a significant role. Along them, due to changes of stress directions, the changes of movement directions of entire tectonic blocks took place. The Lake Vrana depression was opened that way.

Within the description of tectonic and paleogeographic conditions in the area of study, it is necessary to emphasize a fact that, after our cognition, the sea level was about 100 m lower than nowadays and it happened in Quaternary. The whole space of the northern Adriatic sea, the area northwest of the Dugi Otok, was a land, i.e. a wide delta of the river Po. During certain Quaternary phases, practically mere desert conditions existed. During those periods, sand storms were accumulating thick deposits of sand on the mountains that occurred at the delta edges. Their remnants can be observed at the mentioned parts of the islands. By the sea level rise, the present shape of the islands was obtained, as well as a relatively shallow sea (not deeper than 60 m) and numerous islands which are the fragments of once marginal heights of the river Po delta.

Geomorphology of the islands is directly influenced by the lithology and tectonics of that area. First, it is necessary to point out that the islands are elongated northwest-southeast, gently concave toward the open sea. This is also the general strike of the Dinarides along which are trending the described structural units. The islands of Cres and Lošinj are rather hilly, the highest peak of the Cres island is in its northern part, 680 m, and that of the Lošinj island is also in its northern part, 584 m above sea level. The morphologically conspicuous parts of the islands are composed of Cretaceous limestones, whereas dolomite, because of a more intensive weathering, form mainly the depressions, gentle sagging and elongated valleys on the islands. The island coasts are generally rocky, relatively high and poorly liable to abrasion. However, the backs of larger bays (the Cres, Martinšćica, Osor, Mali Lošinj) and the southern part of the island of Cres (Osor, Punta Križa) are lowlands and the land relief gradually descends toward the sea level. There is usually some terra rossa and even marine sediments in those low zones. A specific, flat relief is associated with areas composed of eolian sandy deposits which locally extend till the sea cost on the islands of Lošinj, Unije, Susak and Srakane. The cost is steep also in the area between the villages of Lubenice and Martinšćica that is built of flysch marly rocks. They are deeply cut in some places due to an increased erosion of flysch rocks.

The Cres-Lošinj group of islands is very lacking in arable soil. It is mainly terra rossa - i.e. a reddish brown sandy clay full of carbonate debris. That is the reason why the islands are oriented to the growing of olive-trees and livestock breeding. The thin cover of terra rossa is insufficient for land cultivation. However, large grass-covered areas on the dolomite are suitable for the development of sheep raising that is a traditional branch of the islanders' economy throughout their history. The environmental value of that thin superficial cover is great, although the influence of the polluted Bay of Kvarner are traces at the eastern slopes of the islands. The tests indicate increased values of heavy metals in certain localities in comparison with the situation at the western coast, although there are no major local sources of contamination on the islands. The areas composed of eolian sandy deposits (the islands of Unije, Susak and Srakane) are suitable for farming, however, water is limiting factor in those areas. The production of health food is planned for the island of Unije, while only the viticulture has been developed on the Susak, up to even a commercial degree.

From the previous description, one may conclude that the coast is generally rocky, relatively high and poorly subject to abrasion processes. However, the zones of low relief are similarly important; even now, there are problems caused by sea tides when the conditions are extremely unfavourable. The scenario of anticipated climatic changes till the year 2050 (the rise of sea level for 0.08 to 0.75 m) and 2100 (0.14 to 1.94 m) should not have any major effect on the basic form of the islands, but the low areas will undoubtedly have problems because they appear already in present days. Although the low land occupies only 0.6 do 0.8% of the total area of the islands, these areas are maximally urbanized, thus, the pure share of vulnerable area does not reflect the true state. Practically, all the coastal settlements occur in vulnerable zones, particularly those of Cres, Valun, Martinšćica, Osor, Punta Križa, Mali i Veli Lošinj and Ilovik.

Considerable changes may be expected also in the coastal area between Lubenice and Martinšćica that is partly built of flysch deposits. These deposits are much less resistant to weathering than the carbonate rocks. Therefore, because of the anticipated sea level rise, major falls of flysch deposits may be expected in the parts of coast composed of these deposits due to undercutting. A similar situation exists on the islands of Unije, Susak, V. and M. Srakane and Lošinj were the eolian sands extend till the sea coast. The transport of debris can provoke major collapsing in the coastal zone and endanger otherwise safe settlements. Obviously, only the foreseen rise of sea level in 2100 reaching maximally 1.94 m may cause major harmful effects. The changes of under 0.75 m, foreseen for the year 2050, will not affect significantly the described coastal areas. By maximal sea level rise, the low parts of the Cres island at Osor and Punta Križa will be partly submerged. Even the main insular roads between Osor and Nerezine might be temporary submerged. We emphasize the fact that especially unfavourable conditions may be expected when heavy precipitations coincide with high tides, that is a very frequent case in Croatian coastal areas.

The anticipated rise of temperature till the year 2050 (0.9 do 1.1 °C) will not have major consequences on the rocks and soil of the Cres - Lošinj group of islands. Even the mild increase in precipitation intensity, as well as their concentration toward the winter and spring with a certain deficit in the summer, will happen with already occurred frameworks; although we do not know the real temperature rise trend because the temperature changes still occur in cycles in recent time. However, the temperature change till the year 2100 (2.7 to 3.3 °C) and an already significant concentration of rainfall toward the winter and spring will have a considerable effect on the exchange of soil moisture during the vegetation period, on the evapotranspiration amount and on a remarkable prolongation of the summer- autumn dry season. That prolongation can decrease essentially the covering soil potential, while the increased precipitations may give rise to the disappearance of nutritious substances from the superficial agricultural soil and may also produce flood waves toward the urban areas in the lowland zones of the island.

The anticipated climatic changes cannot be avoided, but the consequences influenced by these changes can be eased by certain measures. In the insular low urban zones, the occasional reconstructions of harbour protection dikes should be made with the progress of those changes. It relates primarily to the sea level rise monitoring and to a precise forecasts of subsequent events because such constructions are very expensive. At constructing the protection dykes, an effective outflow of the increased precipitations should be taken into consideration as well as the appeasing of flood waves in upstream sections of short torrents that includes the construction of small dams. The reduced moisture in the agricultural soil should be solved by watering. The temperature changes would, otherwise, change also the vegetation type on the island. A controlled drainage of arable land will decrease the carrying away of nutritious substances from the soil. The sea level rise will change geotechnical properties of foundation soils because of the increase of pore pressure. This will request undertaking of protection measures for some particularly valuable constructions.

We propose the next action within this project to be the elaboration of the engineering geological map of vulnerable areas of the islands showing those geotechnical conditions that can reflect probable negative consequences caused by the anticipated sea level rise.

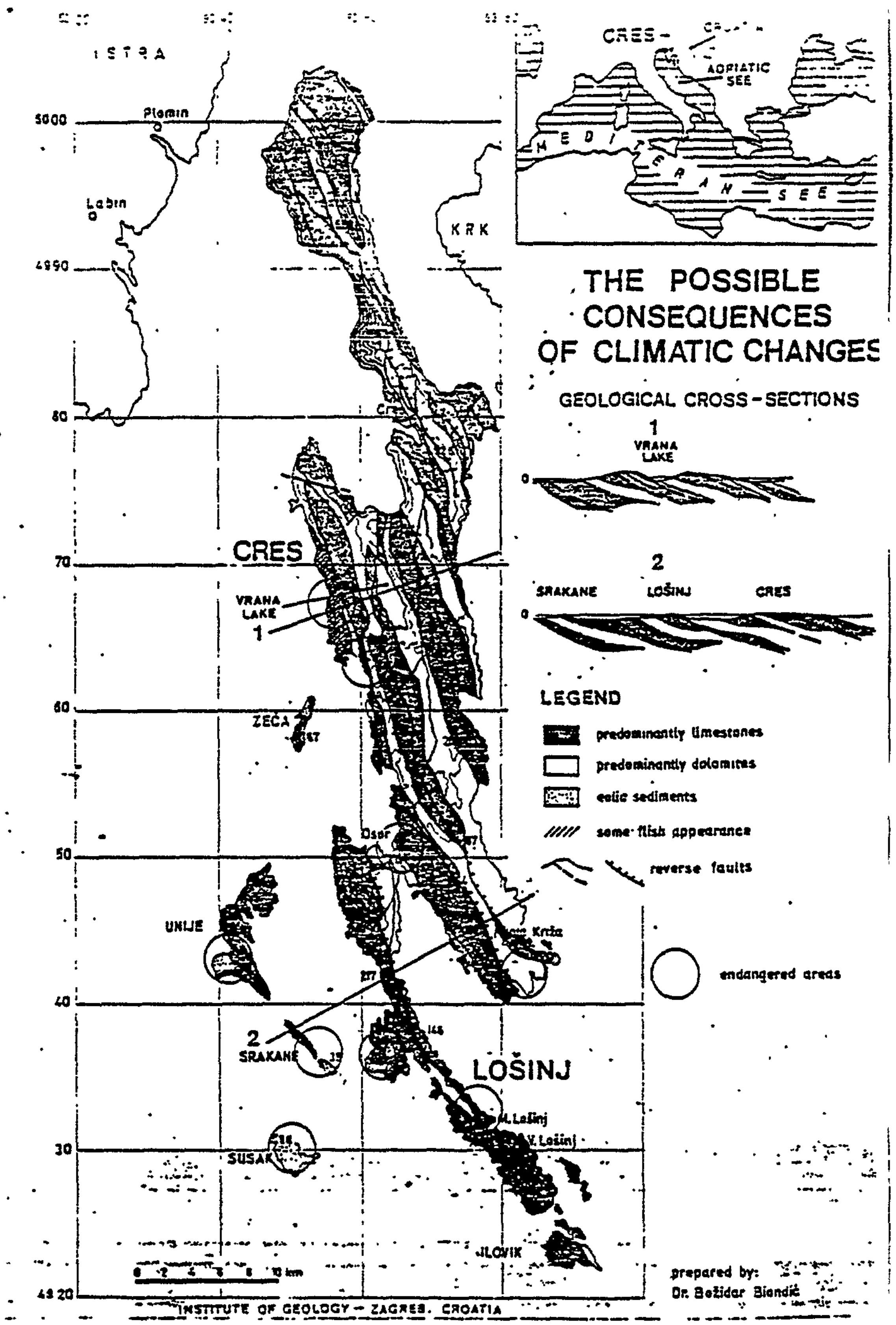


Figure 2.2.1 Lithosphere Map

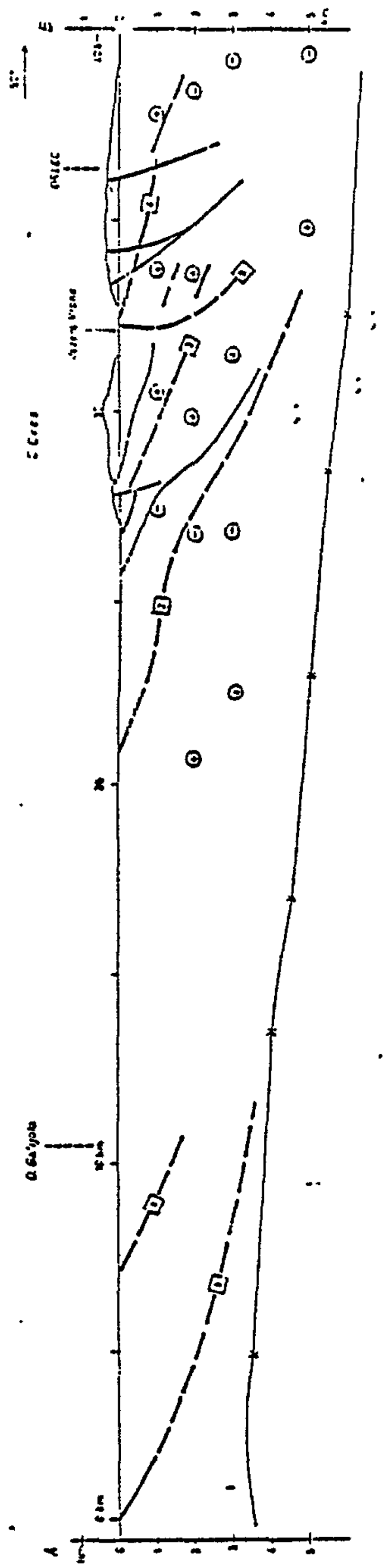


Figure 2.2.2 Structural cross-section

2.3 Hydrosphere

The Cres-Lošinj group of islands is composed prevailingly of carbonate rocks, deformed and fractured during tectonic movement within the subduction zone of the European continent. A manifoldly over-thrusting of carbonate masses (Fig. 2.2.2) and considerably lower sea levels during the geological history made the natural framework for the formation of deep karst aquifers within the Dinaric part of the Adriatic sea realm. Naturally, it happened also within the considered group of islands.

In the very beginning of the description of the hydrosphere, it is necessary to explain that, on the considered islands, although predominantly composed of karstified carbonate rocks, these rocks have very differentiated hydrogeological properties due to their differences in lithological composition, degree of deformations and position within structural forms. On the Cres-Lošinj group of islands, four basic group of rocks are separated, each having different hydrogeological characteristics.

Highly permeable karstified carbonate rocks are limestones of different ages or a complex of rocks in which limestones prevail. The porosity of this rock group is a secondary one, fissured one. The lithological properties, intensity of tectonic deformations and karstification degree influence a high permeability of these rocks. The areas composed of limestones are shaded in the hydrogeological map (Fig. 2.3.1).

Low permeable carbonate rocks are dolomite. The degree of permeability increases with the share of limestones in a dolomitic complex of rocks. They are also the rocks of secondary, fissured porosity, but less karstified, with fissures filled with terra rossa and dolomitic sand.

Impermeable clastic rocks - as the whole unit - are flysch deposits. Marls predominate within these deposits on the Cres-Lošinj islands and they make the whole complex of deposits which is, as a unit, impermeable. Local small springs in the areas composed of flysch deposits are result of water accumulations in the weathered cover.

Low permeable deposits of relatively minor thickness are sandy deposits of eolian origin. They occur on the islands of Lošinj, Unije, Susak and Srakane. They do not form major aquifers, although they have a certain hydrogeological role on the Unije island.

There are no permanent streams on the islands. There are only several short torrential streams toward the sea and the Vrana Lake. The torrents are very rarely active, only during extremely high groundwater stages. For the illustration, it is necessary to point out that the torrents toward the Lake of Vrana were last time active even ten years ago. Similar conditions exist also at the other torrential streams.

The water budget elements of the islands are evaporation, evapotranspiration and effective infiltration into the underground. One can assume the amount of precipitation that enters the karst underground only on the basis of experience from neighbouring continental drainage areas (about 40 %) because the insular runoff from karst drainage areas is associated with numerous small coastal springs, vruljas (submarine springs) and with the Lake of Vrana that is the largest water phenomenon within the area of study.

Numerous coastal springs and vruljas were noticed along the coastal areas of the Cres and Lošinj islands. All these water sites, during dry summer months, either dry up or so diminish that do not posses even a water budget value. It refers to the springs and vruljas at Martinščica, Valun, the bay of Cres, at Punta Križa as well as at numerous sites in the insular beaches where brackish water emerges. All these water sites are result of the drainage of local insular drainage basins without any serious retention capacity. The appearance of fresh water on the island of Unije is also of a local significance. It is an isolated fresh water lens in carbonate rocks of that island. However, the importance of that phenomenon is extraordinary great because this site combined with cisterns make the only source of potable water on that island. The vrulja Vrutak, situated at the southwest coast of the Cres island, between Lubenice and Martinščica, is an exception. Due to its high discharge even during dry seasons, this vrulja was conceptually associated with water losses from the Lake of Vrana. One may see from the hydrogeological map (Fig. 2.3.1) that the coastal springs and vruljas are concentrated mainly to the part of the Cres island where the Lake of Vrana has a central position.

The Lake of Vrana, situated in the central part of the Cres island, as a water phenomenon, has a dominant position and significance. The size of that lake are fascinating for the islands of so elongated shapes as are the Cres and Lošinj. The total area of the lake is 5 km^2, maximal depth is 70 m (60 m below sea level) and it accumulates 220 million m^3 of fresh water. Such amount of entirely fresh water, concentrated at an almost entirely arid group of islands, has provoked an extraordinary attention of researchers during the whole century, the more when one takes into consideration the fact that the lake is the only accurate source of potable water of the entire area of study.

The Lake of Vrana has no characteristics of a typical water phenomenon of the Dinaric karst. That is to say, it has no any visible site where ground water flows into the lake or where it flows out - as it happens at major karst springs. However, there are certain similarities with deep karst lakes in the southern Adriatic sea region. The Adriatic depression is of a tectonic origin, formed along the so-called Vrana fault which was activated by the neotectonic movements. The starting rightwards shear along the Vrana fault was changed, due to the stress direction changes, into a quite opposite direction. So, combined with the rotation of the main overthrust of the Cres island, the lake depression became opened. By this sequence of tectonic events, a space, in predominantly low permeable carbonate rocks, was opened in the central part of the island and it made possible a water breakthrough from the deep karst underground. It is confirmed also by the results of gravimetric measurements of rock density at different depths. Sharp minimums were recorded in the southern part of the lake, where maximal lake bottom depths were measured. They are signs of a lower rock density, i.e. of a relative downward opening of the lake space.

By a detailed geophysical survey (resistivity sounding), it was discovered that basic reverse faults have characteristics of the true over-thrusts dipping up to 25° and inclined toward southeast, with a manifold repeating of rocks placed in the normal superposition sequence. By that, the impermeably flysch and low permeable dolomite - as barriers - enter the deep underground of the island enabling us to take into account the possibility of hydraulic connections of the lake with its local drainage area as well as with a much wider insular drainage area and even with the continental mainland within the Bay of Kvarner and Istria peninsula. All the geoelectric cross sections show multilayered repeating of zones composed of impermeable and low permeable deposits which make natural basic conditions for the formation of deep "confined" aquifers. These aquifers might have distant recharge areas.

During detailed field mapping of the northern and southern flank of the lake, we noticed the existence of not only alluvial deposits but also of quite recent sediments deposited on a rocky coast, "thrown" from the lake water body. These sediments are more characteristic in the southern lake coast. We assumed that this material had derived from a permanent weathering of land slopes composed mostly of dolomite. In order to verify the presumption five samples of that material were taken from different sites and depth for grain size and petrographic analyses. The analysis results were surprising if compared with the environment from where the samples had been taken. The share of carbonates in the residual material ranged between 7 and 34 %, heavy minerals - between 3.1 and 10.4 and light minerals, in which quartz dominated - between 46 and 62 %. Such mineral composition excludes a local origin, from the lake coast, of the analyzed material and this fact is an additional element in discovering the areas from where water comes into the lake. In a petrologist's opinion, there are two possible source rocks of that material. One is - eolian deposits from the large river Po delta and the other is - flysch deposits from the distant Istria peninsula. So, these analyses indicate that the origin of the sampled material should be searched in distant, regional spaces and its transport associate with deep groundwater flows.

A very sensitive job is the use of water as the element in a geological model aimed at understanding the hydrogeological conditions of the lake and of the entire Kvarner area because it is very difficult to obtain any result by using standard hydrogeological methods of exploration due to odd characteristics of this water phenomenon: there are no visible flowing of groundwater into the lake. An attempt of groundwater flow tracing from the hinterland of the Bay of Kvarner was without success. Thus, we decided to apply detailed hydrochemical and isotopic tests in order to find natural isotopes which are also the natural water constituents. The initial hydrochemical exploration directs to a vitalization of lake water in the deepest part of the lake. Physical and chemical composition of lake water corresponds entirely to that of a karst groundwater with only slightly decreased total dissolved solids content near the lake surface. The latter may derive from the direct entrance of precipitation into the lake.

It is necessary to mention that only the first exploration phase of the Lake of Vrana has been completed. In its direct drainage area, the planned observation bore holes have not yet been made. They are aimed at the control of the relationship between water levels in the lake and in the karst underground under different hydrological conditions. However, the obtained exploration results already indicate the concept of lake recharge not only from its local drainage area but also from distant areas. The already defined tectonic and structural features direct us towards the peninsula of Istria (Fig. 2.3.1). The Lake of Vrana we define as a karst polje. It was formed when the sea level was about 100 m lower than nowadays and it was lately inundated by groundwater. In general, the lake stages are controlled by the water level fluctuation in the deep karst underground. The influence of the local drainage area on the lake level fluctuation is obvious due to inertness of the deep karst aquifer of the Bay of Kvarner area. The question is to which degree the local drainage area affects the lake water stages owing to a low permeability of the surrounding carbonate rocks and, even more, does the lake recharges its local drainage area under certain hydrological conditions?

The Lake of Vrana is the only public water-supply source of the Cres-Lošinj group of islands. The attention of insular authorities has been focused at it since a long time. They are conscious of the worth of this lake for the development of the insular municipality. Since 20 years ago, any human activity, except water supply, has been forbidden on and in the vicinity of the lake. Lake water quality has preserved an extraordinary high degree. Meanwhile, a general decline of lake level started in 1982, but we still do not posses accurate data to speak about its obvious trend.

Fig. 2.3.2. shows clearly the lake water level decline from 16 m to 9.27 m above sea level. It is the lowermost level ever recorded, although cyclic falls and rises of lake level have already been noticed, but the decline never happened so expressively nor it lasted so long (Fig. 2.3.3). By early 1982, lake level was at about 14 m above sea level and during the next nine years it dropped for almost 5 m.

The trend of precipitation changes shows similar characteristics (Fig. 2.3.4). The last nine years supervenes an abrupt decrease in precipitation, for about 20 % a year and it was occurring in a row of years. A similar change was also recorded within a much larger Adriatic Sea region. One may find that the mean annual precipitation values were diminished. Monthly maximums were considerably lower and, for that, the effective infiltration into the karst underground was, probably, significantly lower as well.

On the other hand, the mean annual air temperature was slowly increasing during the same period, however, it has not yet reached the maximal value of mean annual temperature, 15.9 °C, recorded in 1982, in the beginning of the lake level falling trend. It is interesting to notice somewhat higher values of air temperature in the winter seasons causing the absence of snow cover on the marginal mountains of the Bay of Kvarner while, as it is known, just the snow cover is a controlling factor of groundwater resources in the dry summer seasons. The main mass of the snow cover melts usually in May.

Evaporation from the lake surface has been observed since 1977. The measurements are performed for spring, summer and autumn months. The evaporation values cannot be linked only to high mean air temperatures because the circulation of air masses above the lake and the degree of air moisture have also strong effects. So, for instance, the maximal air temperature, 33 °C, was recorded in August 1986 but it was not the month of maximal evaporation. Nevertheless, it is necessary to say that a general rise of air temperature brings about also the rise of evaporation from the lake surface.

The amounts of water pumped from the lake have been recorded from 1967, when the annual withdrawal amounted to 136,600 m^3 with an average of 4.3 l/s, to 1999 when 2,238,400 m^3 a year or an average of 71 l/s was withdrawn (Fig. 2.3.7). The maximal pumped quantities, that always occur in the summer, rose substantially, even up to about 130 l/s. The effect of water pumping on the changes of lake water stages has not yet been discovered, even not for only summer months when usually coincide negative effects on the water budget. The lake level usually drops at the rate of up to 1 cm/day during the dry season. It is difficult to find out the reason for that lowering. Such decline of lake level was recorded even earlier, during considerably smaller rates of water pumping from the lake.

The above mentioned data are input parameters of the research project "The influence of anticipated global climatic changes on the Cres-Lošinj islands". The scenario of anticipated climatic changes may significantly affect the hydrosphere of the Cres-Lošinj group of islands. We may say that the present changes, which differ substantially from earlier occurring cyclic changes, may already serve as the indicator of future events.

The coastal springs and vruljas (submarine springs) will change significantly their discharge regime, especially during dry seasons when fresh groundwater flows out in lower rates. The sea level rise in 2050 (0.08 to 0.75 m) will only temporary change the discharge regime. Meanwhile, the forecast for the year 2100 (max. 1.94 m) will already change the fresh water gradients at the sea coast and cause occasionally deep sea water intrusions into the local drainage areas of coastal springs and vruljas. Similarly, the rise of air temperature in 2050 (0.9 to 1.1 °C) will not substantially affect the water budget elements of minor drainage areas. However, the rise of 3.3 °C may effect the rise of evapotranspiration for such a degree that it may result in decreasing the total amount of water. It can occur particularly in the dry summer seasons owing to a change of the seasonal distribution of precipitation at the expense of summer and early autumn months. It is necessary to mention that the coastal springs and vruljas are mostly not used for water supply, but they are very important for the existence of certain fish species in the coastal areas.

The climatic changes will indeed affect harmfully the aquifer on the Unije island. The fresh water lens of that island might suffer significant changes, primarily due to the sea level rise.

The Lake of Vrana is the most interesting fresh water system on the Cres-Lošinj group of islands. The even deteriorating hydrological situation expressed in a permanent decline of the lake level brought rise a public alarming state that lead to launching complex hydrogeological and limnological explorations. The above described results of earlier and the first phase of new explorations demonstrated an evident trend of lake level and precipitation declines and of air temperature rise. Are these changes consequences of permanent climatic changes anticipated in the scenario elaborated by a group of scientists from the University of East Anglia or they are those changes that occur cyclically in the global climate - it is difficult to answer nowadays. According to the events recorded during a 40-year-long observations in the lake area, it is necessary to say that the considered fresh water system will continue to live cycles of long-term decline trends and sharp rises. However, it is obvious that the cycles of water level changes become longer (Fig. 2.3.2) and the last cycle was the longest one and that it resulted with a maximal recorded decline of the lake level. We may say that this downward trend stopped in 1991 and that the present lake level surpasses 10 m above sea level. In whatever way, the observation data indicate that the cycles of decline and rise were alternating in periods lasting 6 to 10 years, thus, we cannot accurately declare whether the trend of decline has ended. In any case, the present state of the lake should be considered as a very unfavourable starting basis for the study of consequences that will occur owing to the global climatic changes.

The hydrological and limnological conditions of the Lake of Vrana can be directly influenced by the anticipated changes of air temperature and precipitation. Till the year 2050, the mean annual temperature may be changed within a range of +1 to +1.1 °C while the average precipitation may rise up to 3 %. The mean annual air temperature in the Lake of Vrana area on the Cres island varies between 14 and 16 °C. The present mean annual air temperature is about 15 °C, thus, the anticipated rise of 1.1 °C could fit the happenings that existed up to now but, by any means, the evaporation from the lake surface will increase. A favourable element is the fact that the anticipated increase of mean precipitation, up to 3%, will mainly occur in the winters and springs, and that is just the time when the lake level used to rise. The time concentration of precipitation will be reflected beneficially onto the lake recharge from its local drainage area. However, the regional influence from the continental mainland may be of a lower degree because it must be considered combined with the air temperature rise, that means a considerably stronger deficit in the snow cover on the marginal mountains of the Bay of Kvarner. The summer dry seasons will be prolonged. This, with the resulting prolongation of the tourism season and a general increase in water supply demand, will naturally result in a greater water withdrawal from the lake. The increase of the mean annual temperature will cause a mild increase of the lake water temperature but it will not deteriorate the pumped water quality since that pumping is associated with the zone of lake thermal stability. The decline of lake level and the increase of lake water temperature can lower that zone in absolute figures, but not so low to endanger the use of lake water and the quality of water in the lower zone. According to the mentioned elements, a gentle trend of lake water level decline could be expected till 2050. This will occur because of a higher evaporation, higher regional air temperature, reduction of the snow cover on the marginal mountains of the Bay of Kvarner, and because of general hydrological conditions in the northern Adriatic Sea region. That mild decline trend need not be associated only with the present state of the lake, because the climatic changes will change cyclically later on as well. It can happen that the lake water level remains at the present altitudes but that it nevertheless represents a general decline trend that will fit into the drastic decline of this 10-year-long cycle.

The anticipated climatic changes till the year 2100 will more considerably influence the general conditions of the Lake of Vrana although the mean annual precipitation will be increased for 9 %. The seasonal concentration of rainfall in the winter and spring will have a favourable effect on the local drainage area and on the rate of water flow from that area into the lake. Combined with the rise of air temperature, up to 3.3 °C, particularly on the marginal mountains of the Bay of Kvarner, a considerable reduction of snow cover and a general water level decline in the karst underground will take place. The latter will be also partly caused by the prolongation of both the summer dry period and of the season of intensive (maximal) pumping from the lake. The changed climatic conditions will have much greater effect on mainland karst springs, where high water waves rapidly run off seaward and, therefore, the underground retention spaces will be changed much faster and to a higher degree because of the prolonged dry season conditions. The general decline of water levels in the karst underground will indirectly cause a further decline of the Vrana lake level. On the other hand, the sea level rise of up to 1.94 m above the present level will cause the rise of the level of the mainland freshwater system and it may be reflected onto the lake itself. The changes of groundwater levels under the influence of sea level rise can produce deep sea water intrusions within the coastal area of the Bay of Kvarner as well as the increase of lake water salinity. At the present time, this salinity amounts to 61 mg/l.

The basic problem of the Lake of Vrana is the origin of its water. The present exploration and plans for further explorations are aimed at solving this problem. Most of this exploration suggests the concept of the water origin from both the local and regional drainage areas. However, for the time being we still have to keep into account the earlier concept of the lake water origin from only the local drainage area, i.e. from the Cres island only. These two concepts request substantially different actions aimed at the preventing or diminishing of climatic change consequences. If the concept of combined local and regional recharge systems is valid, those actions have to be directed toward the continental mainland, that means toward a storage of seasonal high water waves and an artificial recharge of the karst underground during the dry seasons. By that way, the groundwater resource potential of the Kvarner karst underground will be maintained, at least in its general sense. Plans for such actions already exist.

If the local drainage areas is only concerned, substantial hydrological changes should not be expected at the lake but, anyway, the rate of total lake water pumping should be studied carefully. The existing water budget analyses show that the rate of pumping already approaches the upper admissible limit and any increase in the pumped amounts leads us to the mining of water resources. The maintenance of the existing water-supply systems are feasible only under a strict control of pumping rates. In that case, the water-supply development of the considered group of islands could be achieved by linking the insular water-supply system with that one from the Kvarner mainland areas in which the available water resources are already limited.

It is difficult to speak about possibilities for the adaption to new conditions that can be caused by the global climatic changes if the entire natural freshwater system of the Bay of Kvarner area acts already now, during the dry summer season, near to its possible limits when the water supply is concerned. In any case, it is necessary to state that the public water supply of the whole Bay of Kvarner area is based on the use of groundwater and this can function in spite of effects of the anticipated global climatic changes. However, it can be achieved - if the concept of lake recharge from both the local and regional drainage areas is valid - only if high water waves in the Kvarner mainland will be retained by surface storage and if the karst underground of that area will be artificially recharged during prolonged summer-autumn dry seasons.

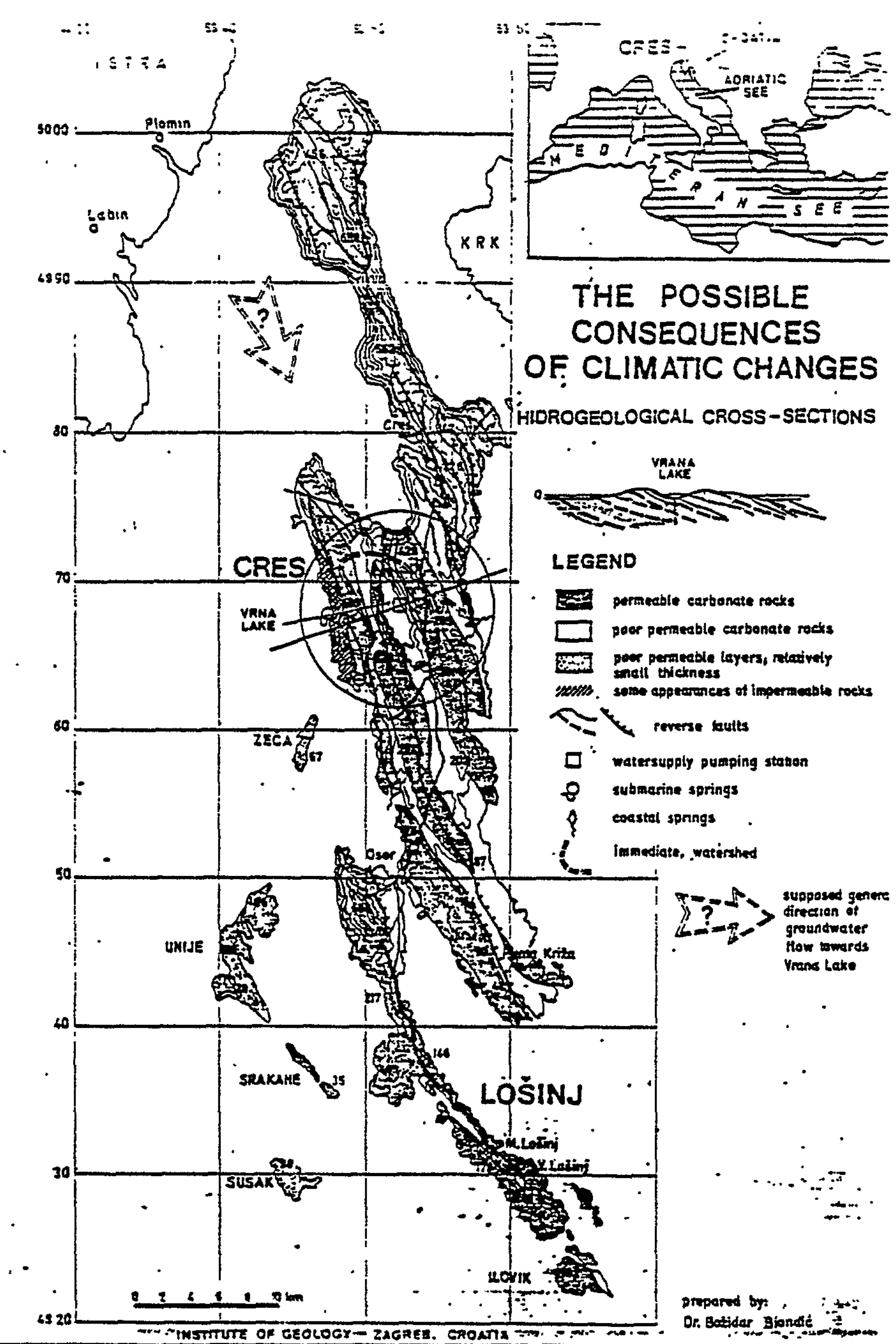


Figure 2.3.1 Hydrogeological Map

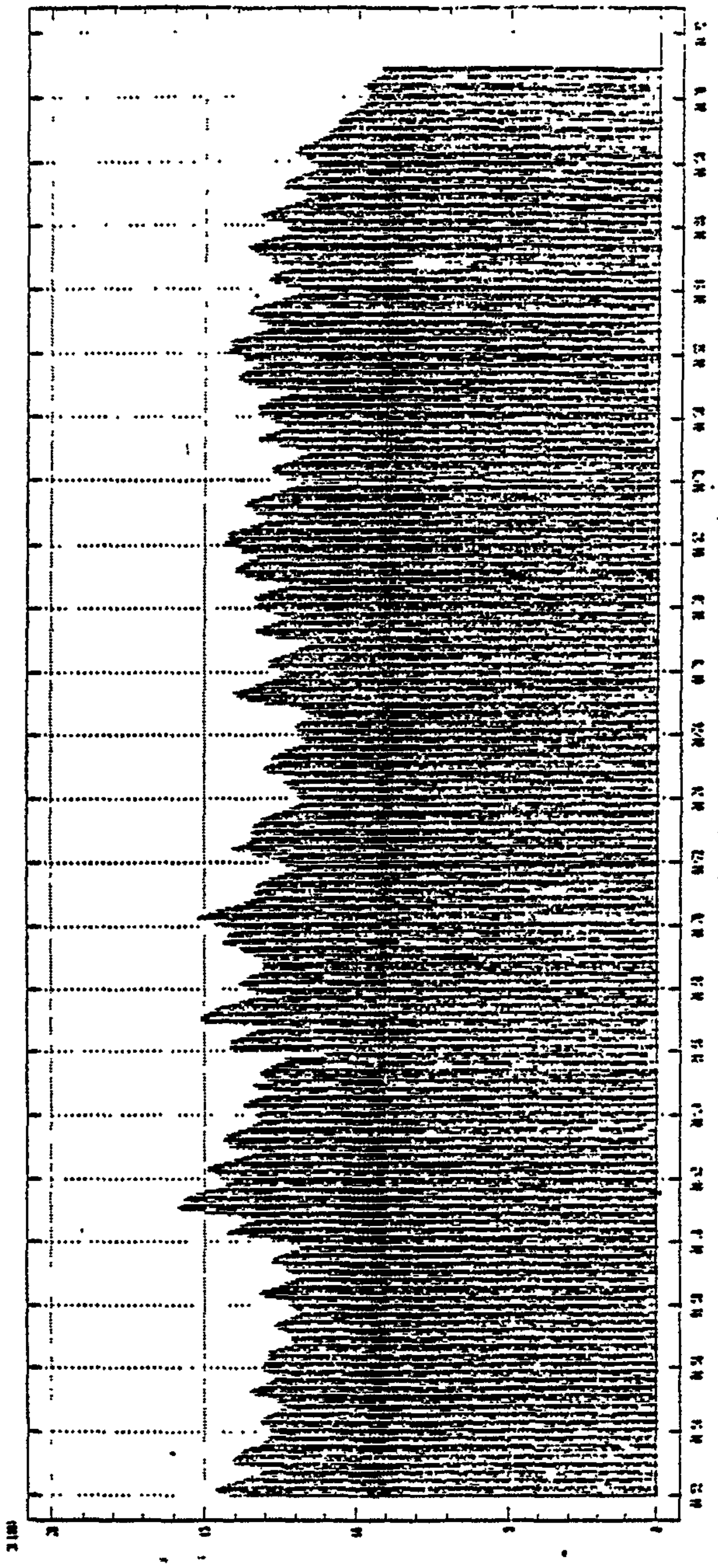


Figure 2.3.2 Mean monthly levels of the Lake of Vrana (1952-1990)

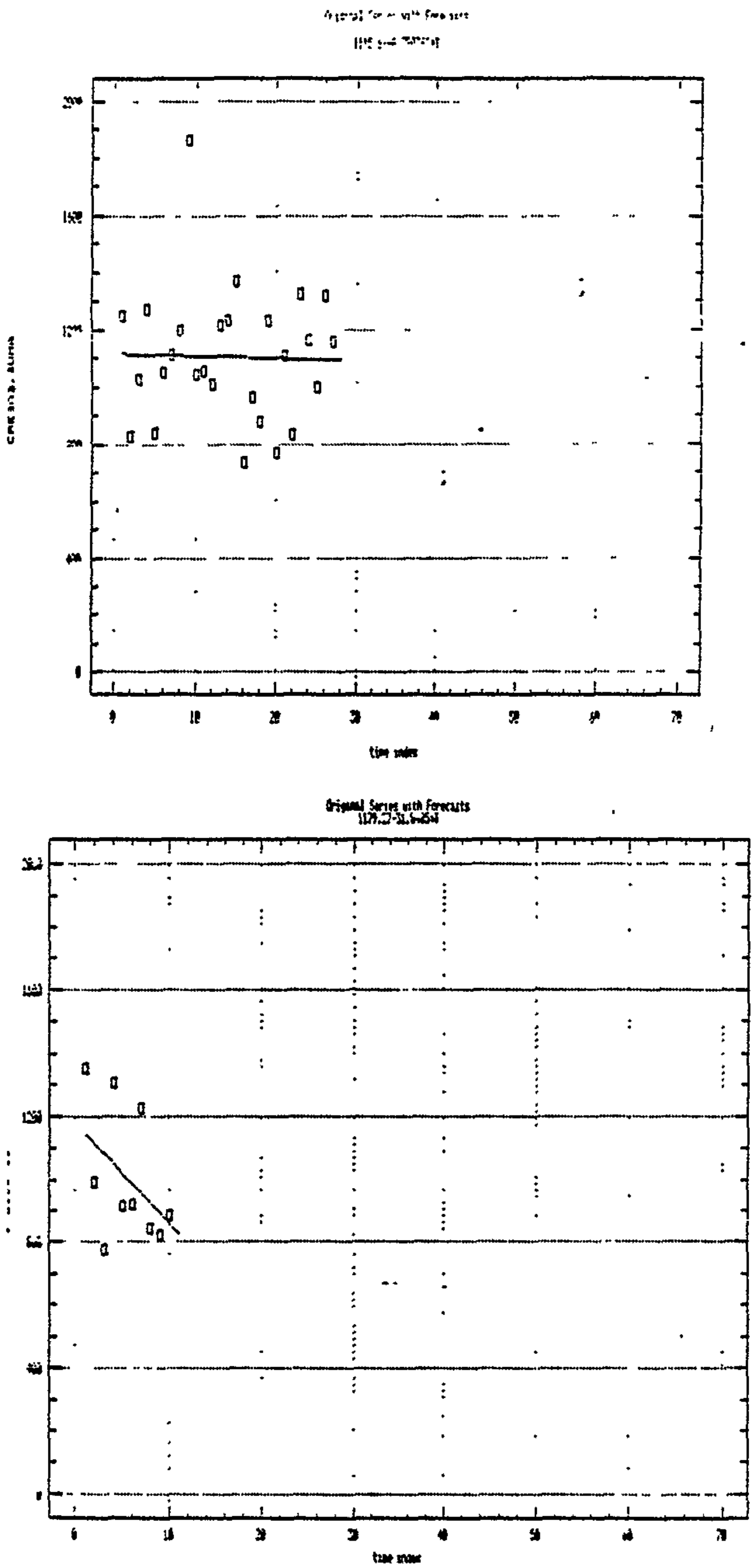


Figure 2.3.3 Trend of lake water level changes

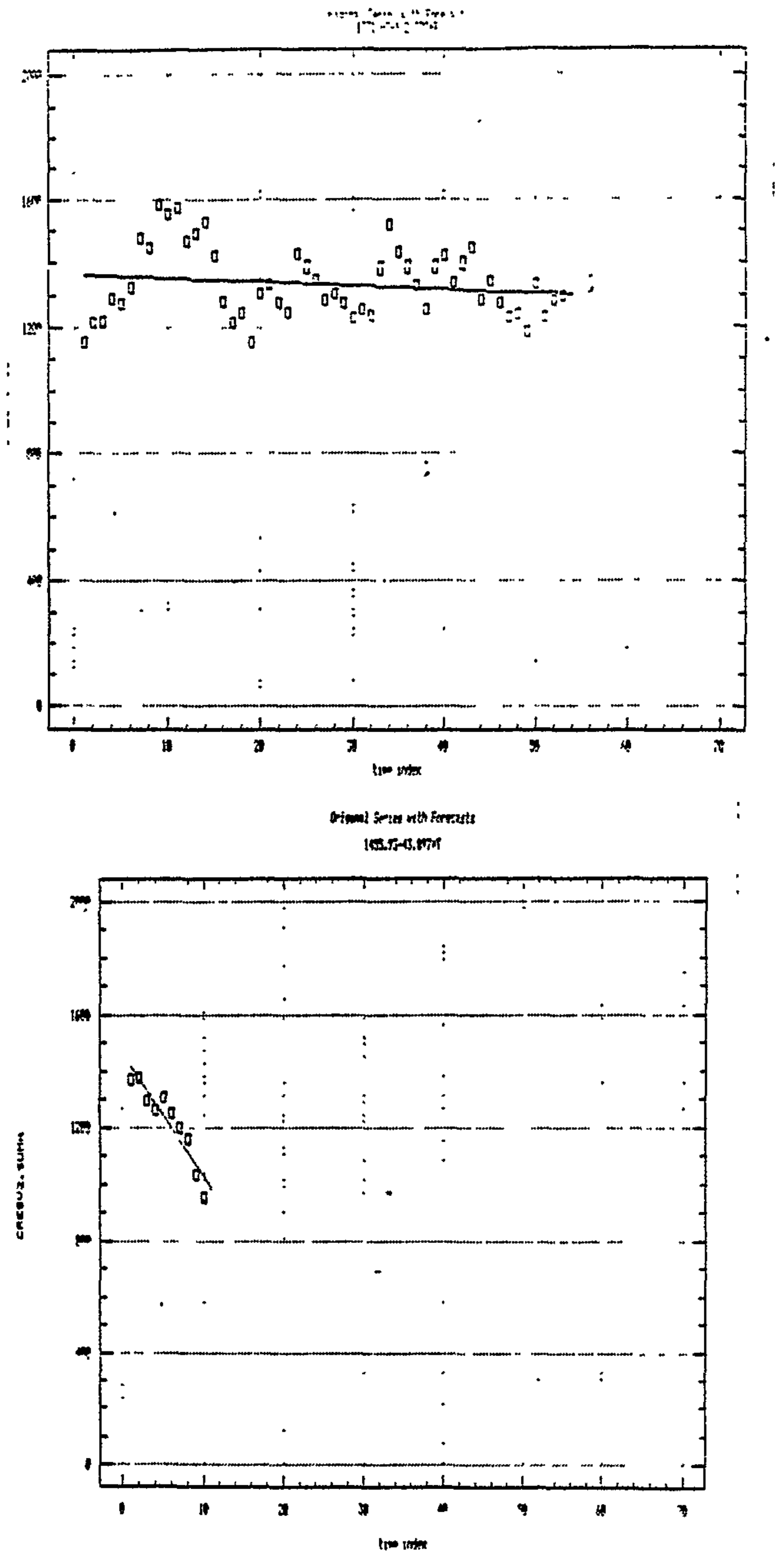


Figure 2.3.4 Trend of precipitation changes (1952-1991)

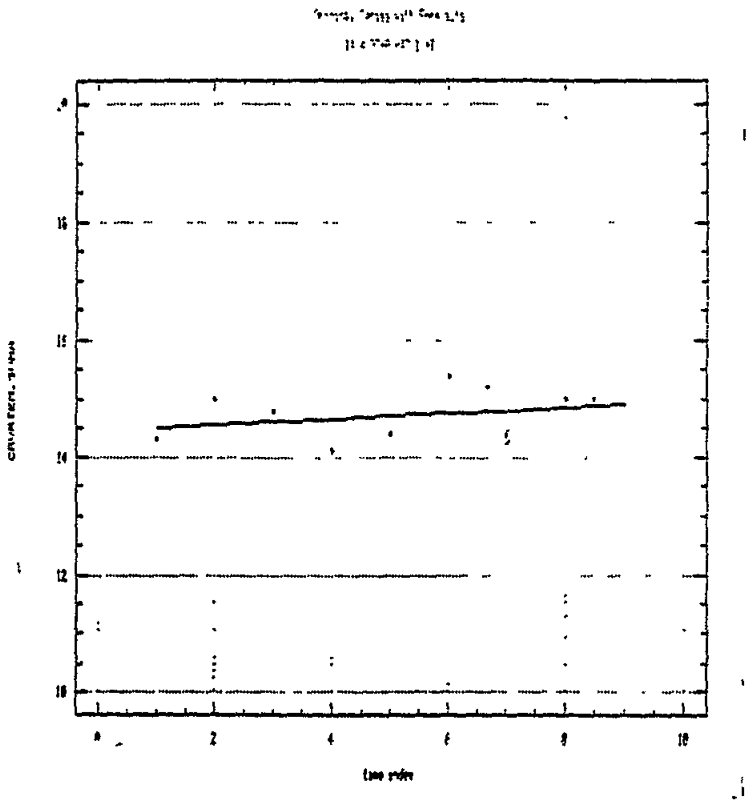


Figure 2.3.5 Trend of mean annual air temperature changes (1981-1988)

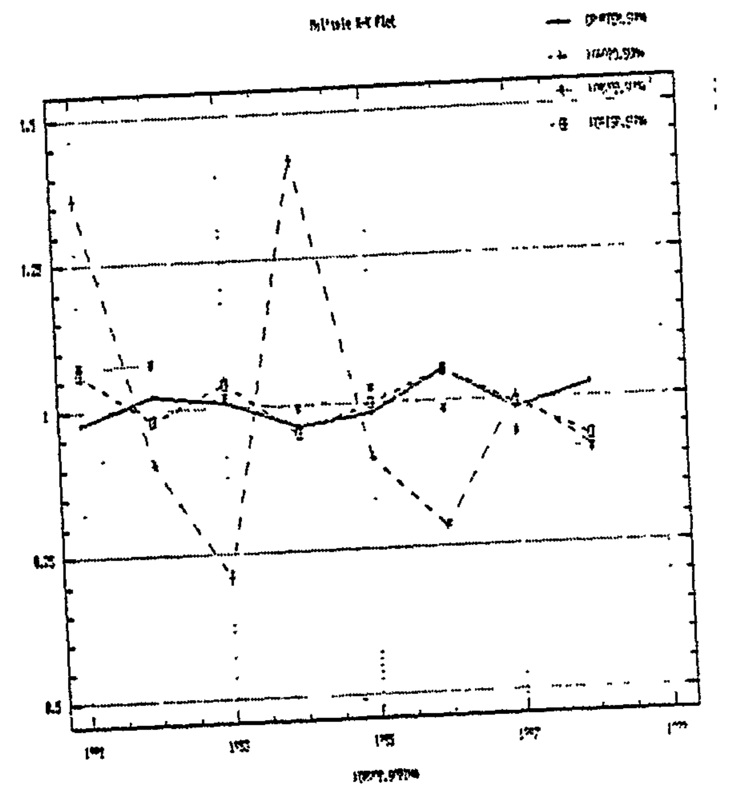


Figure 2.3.6 Precipitation, water level, temperature and evaporation relation (1981-1988)

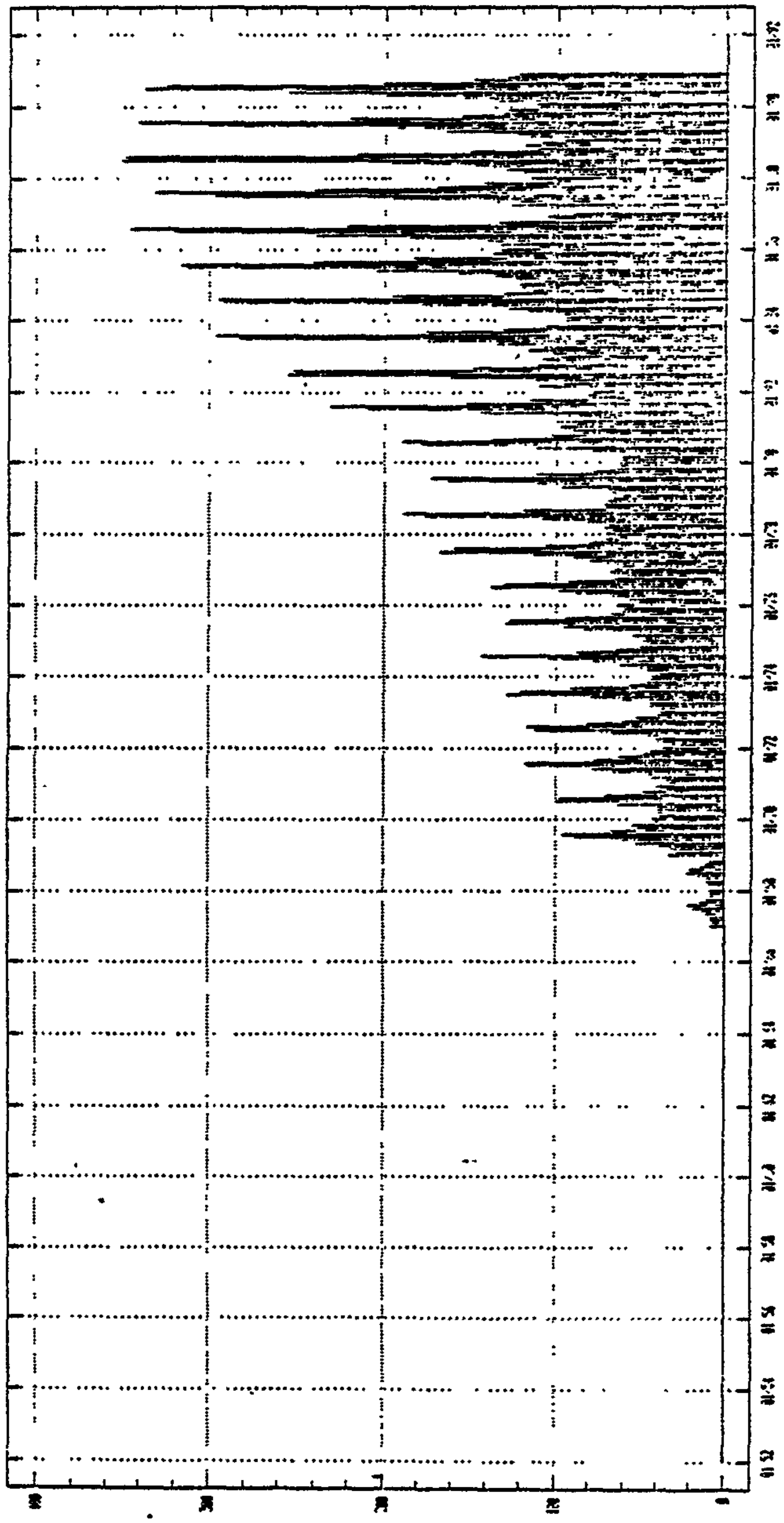


Figure 2.3.7 Monthly amounts of water pumped from the lake

2.4 Atmosphere

2.4.1 Introduction

The atmosphere is the most mobile, well-mixed and pervasive component of the global environment. Thus scientific measurement and understanding of the atmosphere is a world-wide concern. Worldwide co-operative observing and research programmes develop the capability to predict climate in the longer term, including prediction of effects of atmospheric contamination on climate.

To learn more about the influence of man's activity on climatic conditions, the problem of modern climate stability is of major importance. Considering that the present climate seems to be unstable, one should evaluate what consequences may arise from the relatively small global climatic changes which can be achieved in the near future as s result of man's activity. Climatic fluctuations have been common even in the historic past. Having natural origins, there is no reason to expect such fluctuations to be lacking in the future. But today, man through his remarkable technology may also be capable of creating large-scale climatic fluctuations caused by man-made modifications of the composition of the atmosphere. Changing air composition is but one of several ways in which the climate might be affected by human activities; others, for example, include deliberate attempts at weather modification, land usage, and the release of waste heat to the atmosphere.

It is evident that human activities are changing and polluting the atmosphere in many ways. It is not simply local urban air that is contaminated, but the whole global atmosphere. These man-made changes in the planetary atmosphere have occurred over a very short time when measured against the time scale of evolution of the ecosystems of our planet. Among the most serious consequences of the various forms of contamination of the atmosphere on the global scale are:

- climate warming due to increased greenhouse gas concentrations;
- depletion of the stratospheric ozone layer;
- contamination of vital food chains over land and sea by toxic chemicals; and
- acidification of lakes and forests dying due to acid deposition and regional smog.

The main scope of this Chapter is to discuss possible consequences of climate change in respect to air and precipitation pollution, on the basis of available data measured at Veli Lošinj. Average SO_2 concentration data and precipitation acidity (pH) data are going to be correlated with meteorological data, on the seasonal and annual basis. Eventually, they will be considered in connection with developed Mediterranean scenarios (with the Cres-Losinj specifics) of future changes in temperature and precipitation for 2030, 2050 and 2100 years.

2.4.2 Area of the study

Data

The general climatic conditions of the area have been described in the Chapter 2.1. and will not be resumed here. We shall discuss dependence of SO2 concentration data and precipitation acidity data (pH) on prevailing weather types and meteorological conditions for the period of their measurements (1986-1989). Data were analyzed seasonally (three consecutive years with available data), with the purpose to compare the results and find a possible connection with leading meteorological variables. Although the set of data was rather small (1226 SO_2 and 101 pH samples during the period 1986-1989), some interesting results have been obtained. Topography of the Cres-Losinj area, locations of climatological stations and sampling sites are presented in Fig. 2.4.1.

Sources of pollution

Cres and Losinj, with a group of smaller islands, make a part of the Kvarner Bay area. From the West to the East they are surrounded with the complex terrain features. Mountains, that exceed a height of 1000 m, lay at a distance of about 100 km away to the North and to the Northeast, respectively. The urban area (Rijeka) extends about 20 km in a Northwest-Southeast direction in the narrow coastal region. The city of Rijeka has developed into the largest shipyard and harbor on the Northern Adriatic. Besides, the greatest number of pollution sources is assembled here: oil refinery and petroleum industry, cookery, thermal power plant, local industrial sources, heavy traffic, domestic heating. A variety of pollutants, continuously emitted into the atmosphere, associated with characteristic meteorological conditions (strong solar radiation receipt, diurnal land-sea breeze pattern, internal boundary layer development) and orographically induced processes have created serious air pollution problems. Thus, Kvarner Bay has grown up to one of the most polluted areas on the Adriatic coast.

Since there are no significant sources of air pollution at Cres and Losinj, consequences and possible implications of climatic change on these islands, have to be discussed with regard to Rijeka as a main source of pollution.

2.4.3 Air and Precipitation Quality Data

SO_2 concentrations

Sampling of the SO_2 concentration data and the acidity of precipitation has been organized in Veli Losinj on the initiative of The Children's Hospital for Allergic Diseases. Program of measurements is provided by The Public Health Institute of Rijeka.

The fact that there are no significant sources of pollutants on the archipelago can be easily indicated from the SO_2 frequency distribution data. Concentration levels generally show very low concentration levels for both, seasonal and yearly data (Fig. 2.4.2.), with some differences between seasons. Some statistical parameters are given in Table 2.4.1. With the exception of one single sample, observed maximum values do not exceed 100 μg/m3. 5% of data are greater than 40 μg/m3 which is almost three times greater than the average value. Hence, although much behind permissible 24-mean concentration value, these concentrations should not be ignored since they are related with some specific meteorological conditions and enhanced transport of pollutants from the Rijeka area.

Concentrations > 40 μg/m3 will be analyzed separately, in relation with meteorological conditions.

Table 2.4.1. Statistical parameters of SO_2 ($\mu g/m^3$) and pH data for Veli Losinj (1986-1989)

	Year			Winter			Spring			Summer			Autumn		
Data	average	median	st.dev	average	median	st.dev	average	median	st.dev	average	median	st.dev	average	median	st.dev
SO_2	14.7	10.0	15.0	25.7	24.0	13.9	17.0	14.0	14.4	6.2	4.0	7.5	14.5	11.0	16.6
max	193			77			82			75			193		
95-p	42			51			16			43			43		
pH	5.7	5.9	0.9	5.5	5.4	1.1	6.1	6.1	0.9	5.8	5.9	0.9	5.5	5.6	0.8
min	4.0			4.1			4.4			4.1			4.0		

The acidity of precipitation

Acid rain has become one of the major environmental problems facing not only industrialized countries, but the less developed countries too, mainly due to fact that there are no boundaries that could prevent transport of pollutants at large distances, and their deposition to recently pure and unpolluted areas.

Acidity of a substance is associated with the relative abundance of free hydrogen ions (H+) when that substance is in a water solution. Acidity is measured on a logarithmic pH scale where a value of 7 indicates neutrality; decreasing values on the scale indicate increasing acidity and increasing values represent alkalinity.

Absolute pure water has a pH of 7 but if left standing in clean air its pH will decrease to near 5.6, a result of the absorption of atmospheric carbon dioxide to form weak carbonic acid. Most rain water will have this pH value; acid rain is thus consider to exist when pH is less then 5.6. For this increased acidity to occur, the atmosphere must contain chemicals to provide an acid source (Smith, 1981).

Acid precipitation primarily results from the release of sulfur and nitrogen oxides (SO, NO) into the air by industrial and transportation sources. It is more regionally than locally conditioned, although there are some circumstances (domestic heating, vegetation, sea salt) that can force up or enhance acidifying processes at certain locality.

For the period of 1986-1989, a series of 101 precipitation sample has been analyzed. Seasonal and annual frequency distributions are shown at Fig. 2.4.3. Almost 30% of data (except for the spring) indicate values less than 5, with minima around 4, in all seasons. Events with pH < 5 will be particularly analyzed in connection with weather types and prevailing winds that bring pollutants from other regions.

2.4.4 Meteorological Aspects of Air and Precipitation Pollution at Cres-Losinj Islands

Synoptic weather patterns

Individual large-scale synoptic patterns have been used as analogs against which day-to-day weather is compared for the period of 1986-1989. The statistics of occurrence of a given type and its evolution are very useful in understanding the overall flow configurations. This analog type of approach has been frequently applied and cited in the literature (Poje, 1965; Hess and Brezowski, 1969; Dayan, 1986; Dayan, 1989). Although classification of synoptic situations into distinct weather types cannot be applied in all cases, it enables us to describe in general terms the more prevalent situations.

A modified Poje's classification is applied to the Northern Adriatic, based mainly on the positions of the anticyclones and their influence on the development and positions of major low-pressure systems in this area. This classification is similar to Dayan's (1989), with the two types added for the account for two groups of situations that have appeared important for the Northern Adriatic, especially regarding episodes of air and precipitation pollution. Brief description of the seven main synoptic weather patterns are the following:

Type 1: Anticyclonic type. An anticyclone covers the Northern Adriatic or larger area (Mediterranean).

Type 2: Bridge or a ridge of high pressure covers the Northern Adriatic. A bridge of high pressure, between two depressions, has an axes W-E oriented in winter and SW-NE in summer. The ridge is coupled mostly with the anticyclone in Western Europe or Azores. Weather pattern is generally anticyclonic.

Type 3: Cyclogenesis in the Bay of Geneva or depression in the Bay of Trieste and the subsequent cyclone's movement along the Adriatic's, especially during the winter period.

Type 4: Low pressure trough (with a N-S or NW-SE axis); depression dominates over Northern Europe.

Type 5: Zero pressure gradient field over the Adriatic, summer situations predominantly.

Type 6: Southeasterly or Easterly type over the Northern Adriatic. Two cases are possible: Northern Europe is dominated by an anticyclone. Pressure is relatively low over the Mediterranean, or pressure is relatively low over northern Europe, anticyclone dominates central and southern Europe.

Type 7: Other transitory, mostly westerly types.

Weather types 1 and 2 are the most common types during the winter (Table 2.4.2.) while the type 5 (light winds) prevails during the spring, summer and the autumn.

Cyclonic situations (types 3 and 4) are more often in spring and winter. The statistics of occurrence of described weather types are given in Table 2.4.2 and shown at Fig. 2.4.4.

Distributions of wind strength (Beaufort) and directions for each weather type and season are shown at Fig. 2.4.5.(a-g) and 2.4.6.(a-g). Briefly, weather types 1 and 2 are mostly related with winds from NW-NE directions, while types 3 and 4 (cyclogenesis in the Bay of Geneva) are connected mostly with southerly winds, with seasonal differences.

There is a great number of situations with a light winds in the zero pressure gradient field, when locally driven circulation pattern is evident (sea breeze effect).

Table 2.4.2. Relative frequency (in %) of synoptic weather patterns (Type 1-7) during the period of 1986-1989 for the Northern Adriatic

Weather pattern	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	All types
Spring	2.1	4.8	6.3	2.6	7.6	0.4	1.4	25.2
Summer	1.5	4.1	1.4	3.6	13.6	0.0	1.0	25.2
Autumn	6.4	3.7	3.2	3.8	7.1	0.5	0.2	24.9
Winter	6.6	4.5	3.6	3.8	2.7	2.4	1.1	24.7
Year	16.6	17.1	14.5	13.8	31.0	3.3	3.7	100.0

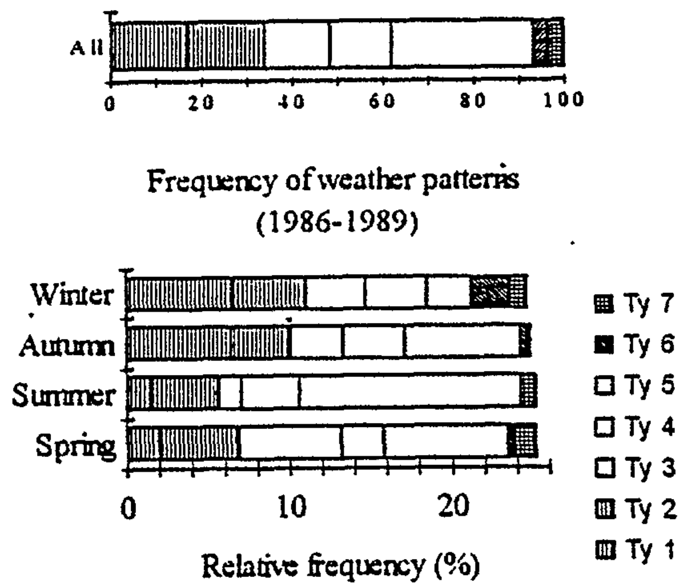


Fig. 2.4.4 Frequency of daily weather patterns for seasons during period 1986-1989

SO$_2$ concentrations

Although the overall air pollution is small, differences between seasons are markable (Fig. 2.4.2. Table 2.4.3.). Mean concentrations in winter are more than four times greater than in summer (26 against 6 $\mu g/m3$). 50% of data have values less than 10 $\mu g/m3$, so this value can be viewed as the upper level for the background pollution at Cres-Losinj. The values greater than 40 $\mu g/m3$ might be perceived as the extreme ones for these islands, since they are probably brought in from other regions. Relative frequencies of occurrence of synoptic weather patterns are given at Fig. 2.4.7.(a-d) for five classes of SO$_2$ concentrations. Similarly, distribution of concentration classes for each weather type is given at Fig. 2.4.8.(a-e).

Table 2.4.3 Percentile values of SO$_2$ concentrations for year and seasons (1986-1989)

Percentiles	10	20	30	40	50	60	70	80	90	95	98	99	99.5	99.9	max
Year	3	3	4	7	10	13	18	24	34	42	56	67	75	85	193
Winter	7	13	17	21	24	28	33	38	44	61	67	63	65	77	77
Spring	3	4	6	11	14	18	22	26	34	43	64	73	74	82	82
Summer	3	3	3	3	4	4	6	7	12	16	22	39	71	75	76
Autumn	3	3	5	8	11	13	16	21	28	43	65	79	85	193	193

It can be seen that both, anticyclonic (weather types 1 and 2) and cyclonic (weather types 3 and 4), are generally related with higher levels of concentration, especially in autumn and winter. Although the Grosswetterlagen classifications are very useful to form the overall picture, each individual weather system has its own unique characteristics and may greatly influence the transport of pollutants to the region. The very simple picture of the flow at Cres-Losinj is presented at Fig. 2.4.9., indicating that two main groups of wind directions dominate in all seasons: SE-SW winds are often in cyclonic situations and transitory weather types, while winds from NW-NE directions are related to weather types 1 and 2. In most situations northerly winds start to blow during and immediately y after the low depression movement eastward from the Bay of Geneva. It is often hard to associate a wind direction to the weather pattern. The other more specific methods should be applied.

The acidity of precipitation

The main process that results in acid deposition is the removal of chemicals through precipitation - the "wet deposition" process. Atmospheric impurities are incorporated in the entire precipitation process, starting with cloud droplet formation, and are deposited as part of the eventual precipitation.

Acid rain primarily results from the release of sulfur and nitrogen oxides which are transformed into sulfuric and nitric acid. Given that pollutants can return to earth almost immediately or remain aloft for a week or longer, than atmospheric circulation patterns and prevailing winds are significant. Preliminary analysis suggests that some 30% of the total sulfur compounds deposited over the eastern United States originate from site sources more than 500 km away from the region (Oliver, 1987). Another 30% comes from sources between 200 and 500 km, with the reminder being derived from sources less than 200 km from the deposition site. Location of the actual source of chemicals contributing to acid rain is a distinct problem. Therefore, conclusions about that should be made on the base of relevant data.

This problem is evident at Cres-Losinj islands too. Sources of pollution at the archipelago are almost insignificant. The closest area from which pollutants might come is the Rijeka Bay, about 90 km away from Veli Losinj (the only measurement site).

During the period of measurements (June, 1987- December, 1989) 101 precipitation sample was collected and analyzed. In another words, those data comprised about 13% of the whole data range. Number of cases range form 20 and 21 in winter and spring seasons, to 29 and 31 in summer and autumn. Frequency distribution (Fig. 2.4.3) shows that almost 50 % of all data have pH less than 5.6. Looking the seasons, we may notice that winter and autumn are the seasons with more often acid events, with minima around pH=4. Average seasonal precipitation amount was 13 mm in autumn and winter, 8.4 mm in summer and 11mm in spring.

Dependence of pH less than 5, as well as great than that value, on weather types is given at Table 2.4.4.

Table 2.4.4. Relative frequency (%) of occurrence of pH ≤ 5, and > 5 in dependence on seasons for each weather type, 1987-1989

Weather pattern	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6	
pH	≤5	> 5	≤5	> 5	≤5	> 5	≤5	> 5	≤5	> 5	≤5	> 5
Spring	0	0	5	19	10	28	5	14	9	10	0	0
Summer	0	0	0	14	7	10	3	7	41	17	0	0
Autumn	10	0	3	0	23	19	3	3	20	13	3	3
Winter	5	0	25	0	15	15	10	0	10	5	5	10

For weather type 7 there was no data.

During the spring months about 30% of samples were acid while in winter situation is opposite. A greater alkalinity in spring might originate in Veli Losinj from impurities in the air that are not man-made produced (i.e., pollen, needles, dust, organic compounds of trees, insects, birds, etc.).

The analyses show that acid rain appeared in all weather types, but dominantly in connection with cyclonic ones, but, it is evident in anticyclonic situations, too (winter and autumn). Pollutants could be brought up to this area by mainly two groups of winds: southerly and northerly. Besides, the Rijeka Bay area, which certainly could be indicated as one of the defendants for the pollution on the scale that includes the Cres-Losinj archipelago, some other industrial regions in Europe and northern Italy could participate too (Fig. 2.4.10.).

The connection between pH value and the corresponding precipitation amount is given at Fig. 2.4.11. Although correlation coefficients are low, there are indications that low amounts of precipitation are in relation with higher pH values (stronger alkalinity).

Figures 2.4.12. and 2.4.13 show absolute frequency distributions of wind strength and direction in situations with precipitation.

Although analyses have not confirmed any significant dependence on temperature, some results connected with insolation data are apparent. In Table 2.4.5., a number of days with concentration levels > 40 $\mu g/m3$ and pH values < 5 is given in connection with the average seasonal insolation. It can be seen that small average insolation is connected with pollution episodes.

Table 2.4.5 The average seasonal number of sunshine hours (insolation) in situations with pH < 5, and SO_2 > 40 $\mu g/m3$

Season	Insolation (hours)	Number of days with $SO_2 > 40\ \mu g/m^3$	Number of days with pH < 5
Winter	4.8	36	8
Spring	8.2	18	4
Summer	10.5	3	8
Autumn	4.3	22	12

2.4.5 Expected Effects of Possible Climatic Change on Cres-Losinj Islands, Most Vulnerable Systems and Activities

As has already be mentioned, air pollution is one of the most widespread and highest-priority problems at the present time, not only because of the range of its direct damage, but also because of its possible consequences on penetration into the various other media of pollutants which are directly emitted into the air.

Besides the impacts of pollutants on the biota, there is the further serious problem of their possible influence on the climate, through anthropogenic warming and contamination of the atmosphere with aerosols and trace substances, which change the atmosphere's composition.

Human induced climate change can have serious consequences for the social, economic and natural systems. What changes could be expected in some smaller regions as the Cres-Losinj archipelago is, is not so easy to say. Projected changes in global temperature and precipitation are still uncertain, so, comprehensive estimates of the physical and biological effects of climate change at the regional level are difficult.

Despite these uncertainties, it is important to discuss possible unfavorable effects, and to try to reach some conclusions.

The site-specific scenario for the Cres Losinj archipelago, prepared by the University of East Anglia, is used to assess major effects and possible consequences of air pollution in connection with meteorological conditions.

Major findings and principal issues

Series of air and precipitation pollution data, collected during the period 1986-1989, are still to short to make conclusions with the statistical significance. However, the analysis of data enables us to discuss major results.

Significant correlation between temperature and air pollution is not found, but it can be noticed that it is not possible to connect lower values of SO_2 concentrations, that predominate at the area, with any specific weather type, or meteorological variable. Higher values of SO_2 concentrations (> 40 $\mu g/m^3$) seemed to be more often in connection with lower mean temperatures in all seasons, particularly autumn and winter.

There is no evidence that rise in temperature could affect directly pollution levels, but homogeneous and heterogeneous reaction rates and transformations of pollutants could be induced. Further, in addition to the expected increase in mean temperature by several degrees, a change in extreme events can also be expected with changes in circulation patterns, too. They could influence a redistribution of atmospheric systems in time and space, causing changes in wind intensity, cloudiness, insolation and other parameters. These changes could be the cause of more often pollution episodes.

The predicted changes in temperature, precipitation and frequency of extreme events might enhanced the air pollution in the area related to the emissions from the whole Kvarner Bay. Due to the temperature rise, orographically induced effects and local circulations in Kvarner Bay could intensify. Stronger northerly winds might be more frequent, causing the transport of pollutants towards the Cres-Losinj archipelago.

From the MSL pressure scenarios it appears probable, on the basis of the model evidence, that the pressure changes will be small. The model-average changes are much less than the normal inter-annual variability of MSLP. So it can be assumed that frequencies of characteristic weather patterns would not change significantly. But due to the expected temperature rise, especially in summer periods, a situations with a ridge of a higher pressure could be more persistent, enhancing persistence of anticyclonic formations from July to October that already exist at the Northern Adriatic.

Considering the intensity, for both, cyclonic and anticyclonic weather types, intensification of processes might occur. Interactions between the atmosphere and surface (orography) might have caused enhanced vertical turbulent energy exchange, convection processes and more precipitation, mainly in autumn and winter, which is in accordance with the predicted scenario for precipitation. Acid precipitation is more often in winter and autumn seasons, consequently, number of cases with low pH values might be greater, and acidification of soils and vegetation might be stronger.

All those processes are connected mainly with transport of pollutants from other regions (Rijeka Bay, Northern Italy, Central Europe), they do not originate at Cres-Losinj area.

However, since the present concentrations at the archipelago are generally low, significant changes in air pollution are not to be expected, in spite of the extreme events that might be more frequent, especially in autumn and winter.

Since it appears that Cres-Losinj area is very sensitive to pollution originated from the area of Rijeka, the events of higher pollution could be avoided by taking appropriate technical measures and by lowering emission levels in the whole Kvarner Bay area.

Substantial scientific uncertainty still remains concerning the nature of changes, so steps to understand and foresee the impacts on natural resources and the entire society as well, should be undertaken further. Studies of the frequencies of extreme events and how these events relate to the climate conditions should continue, together with the proper control of pollution levels. More extensive observing and monitoring system should be provided for such purpose.

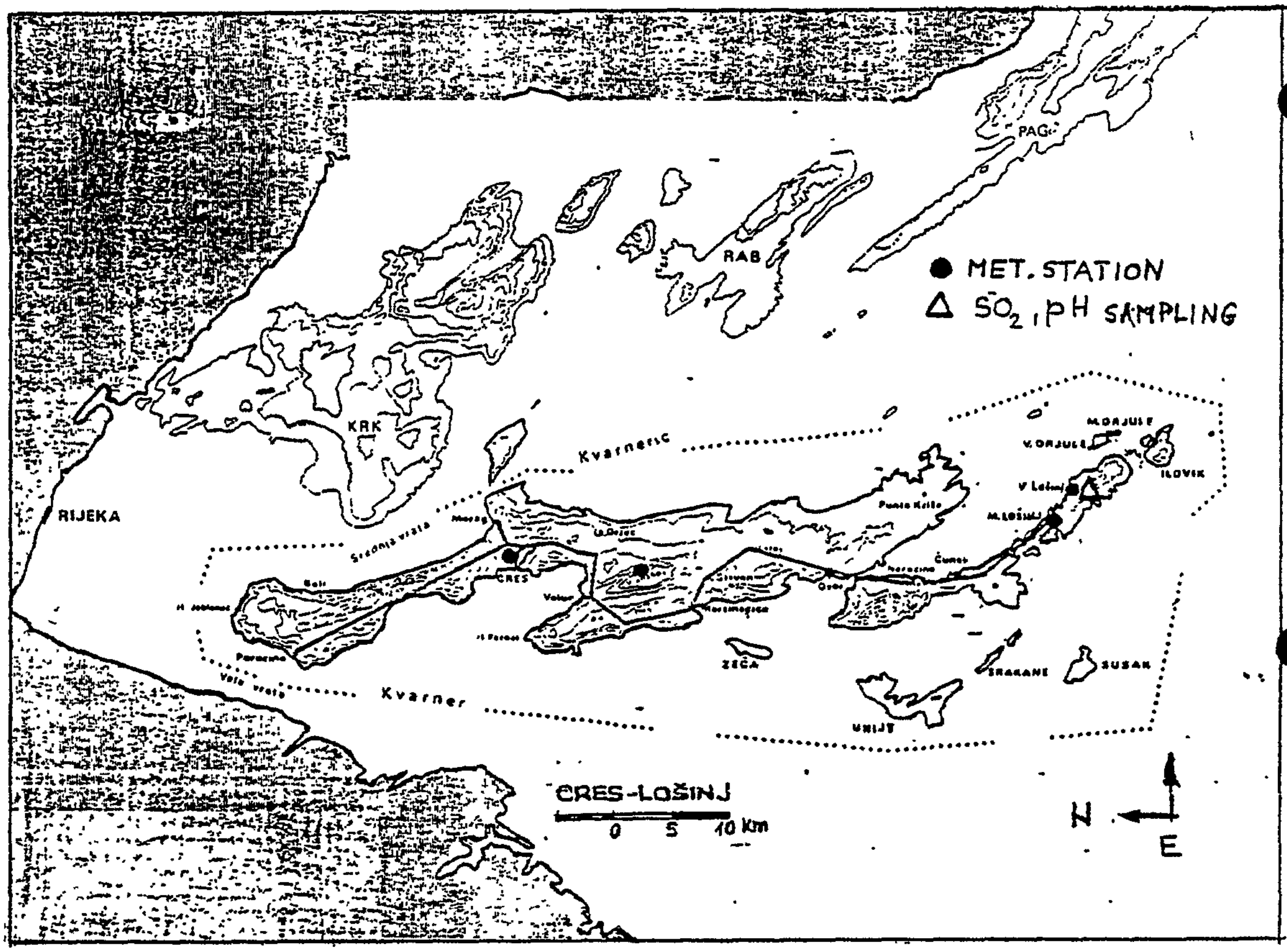


Figure 2.4.1 Topography of the Cres-Losinj area with meteorological and air/precipitation quality measurement sites

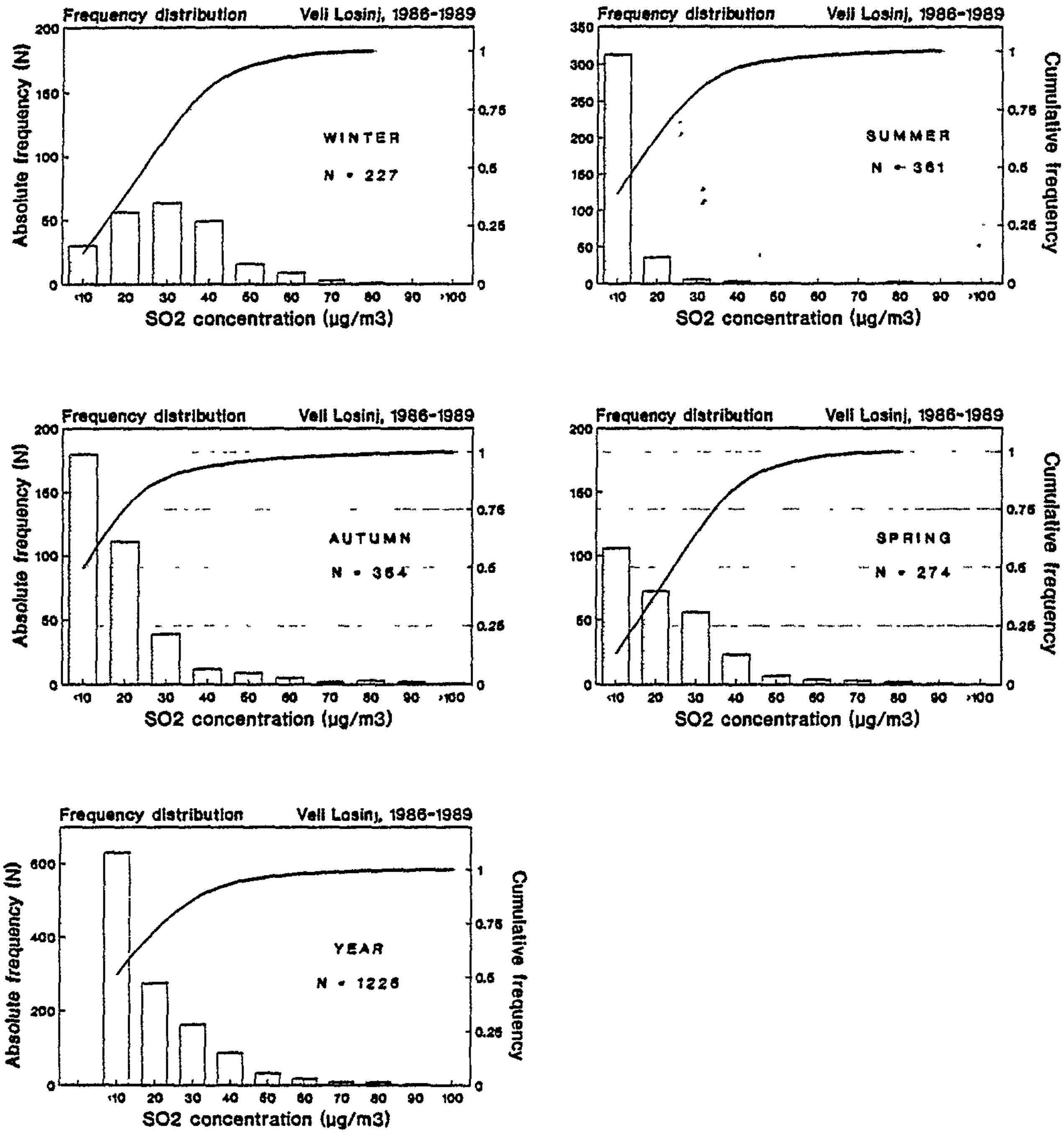


Figure 2.4.2 Seasonal and annual frequency distributions of SO_2 concentration data for Veli Losinj

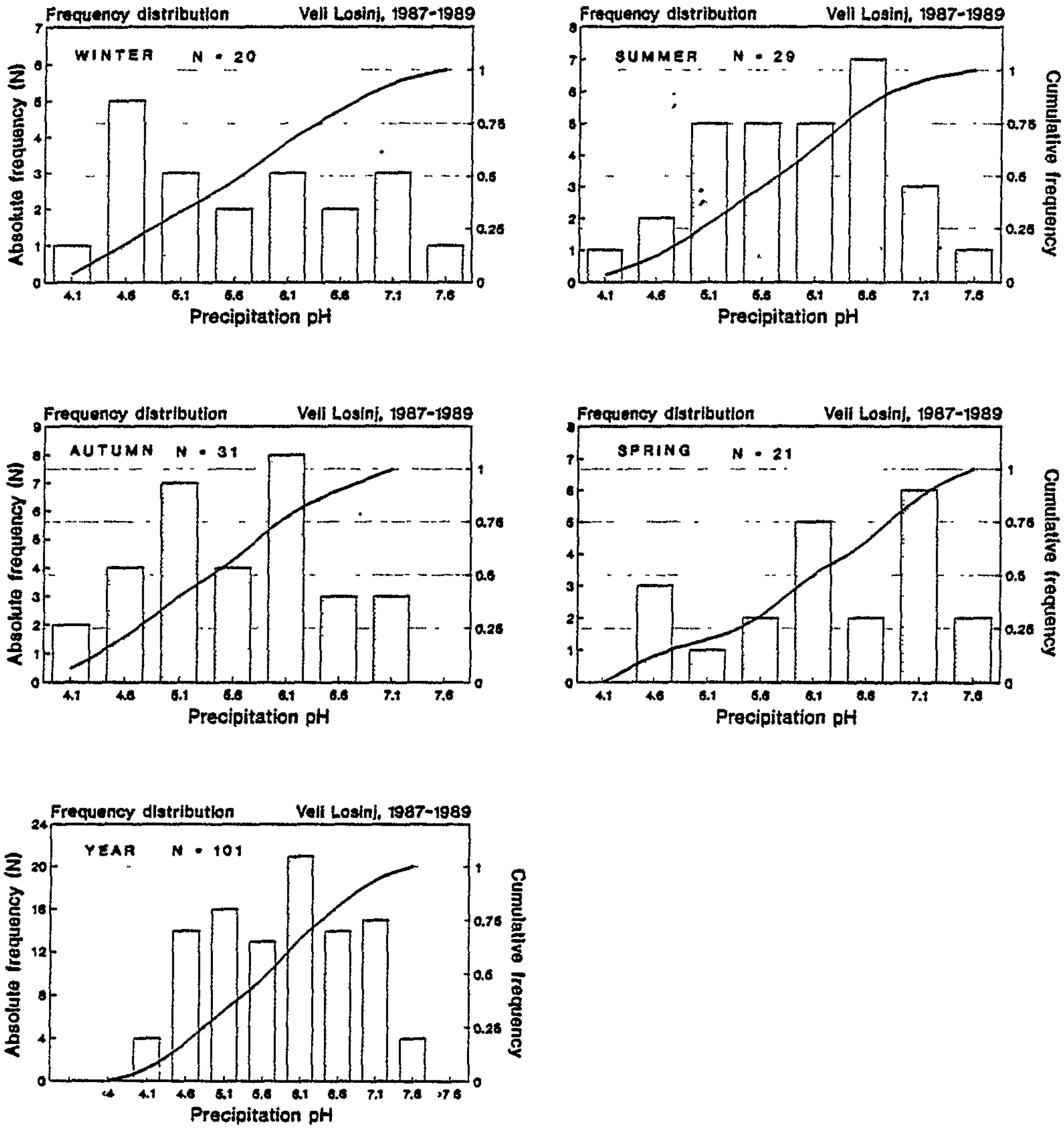


Figure 2.4.3 Seasonal and annual frequency distributions of precipitation acidity (pH) data for Veli Losinj

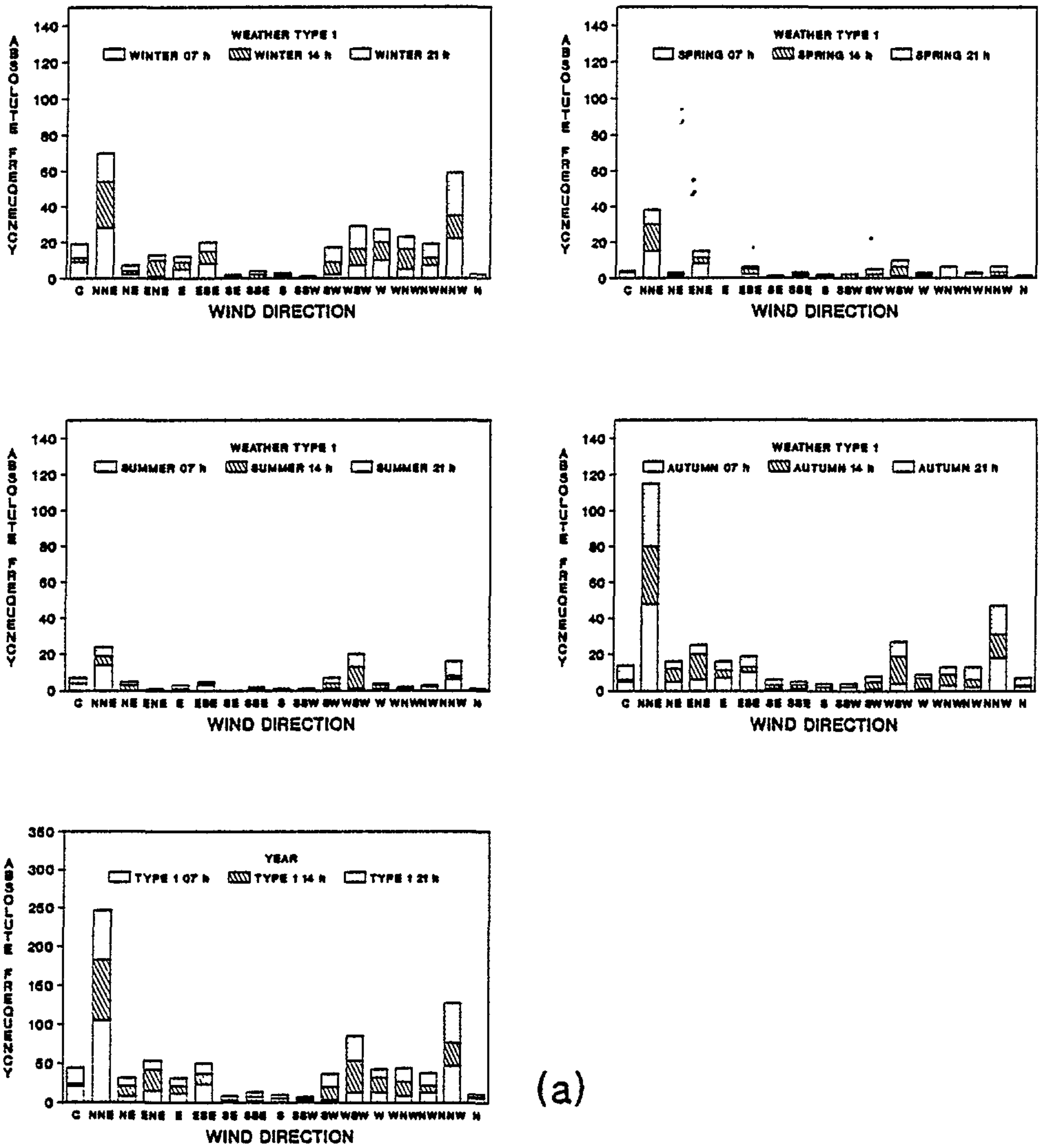
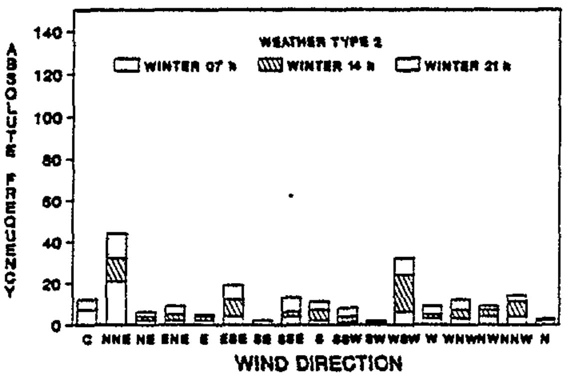
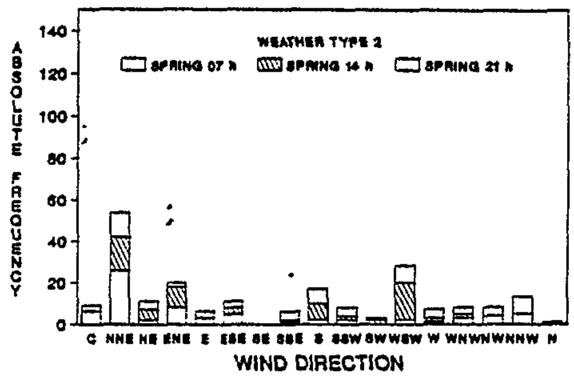
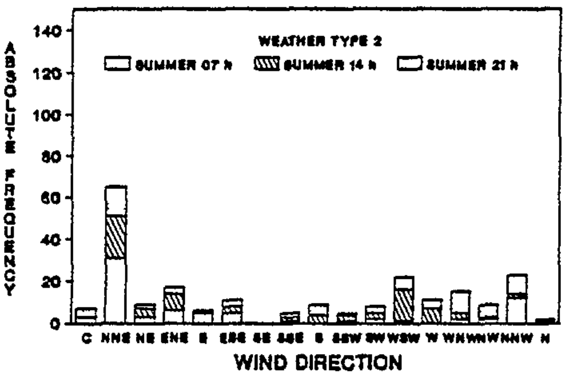
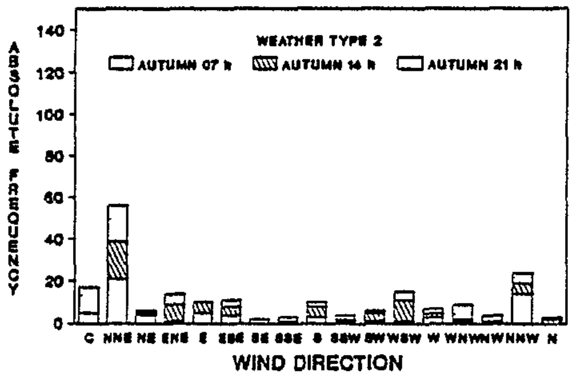


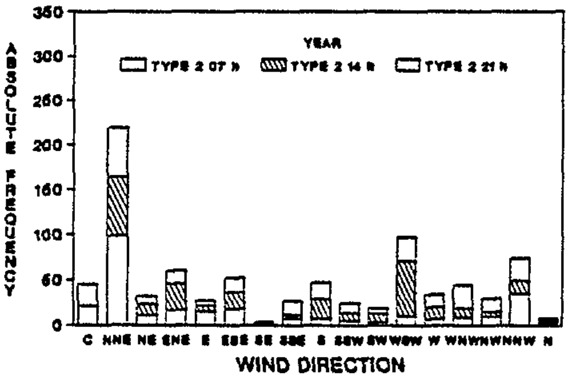
Figure 2.4.5 Seasonal and annual wind distributions for each weather type
a) Type 1, b) Type 2, c) Type 3, d) Type 4, e) Type 5,
f) Type 6, g) Type 7





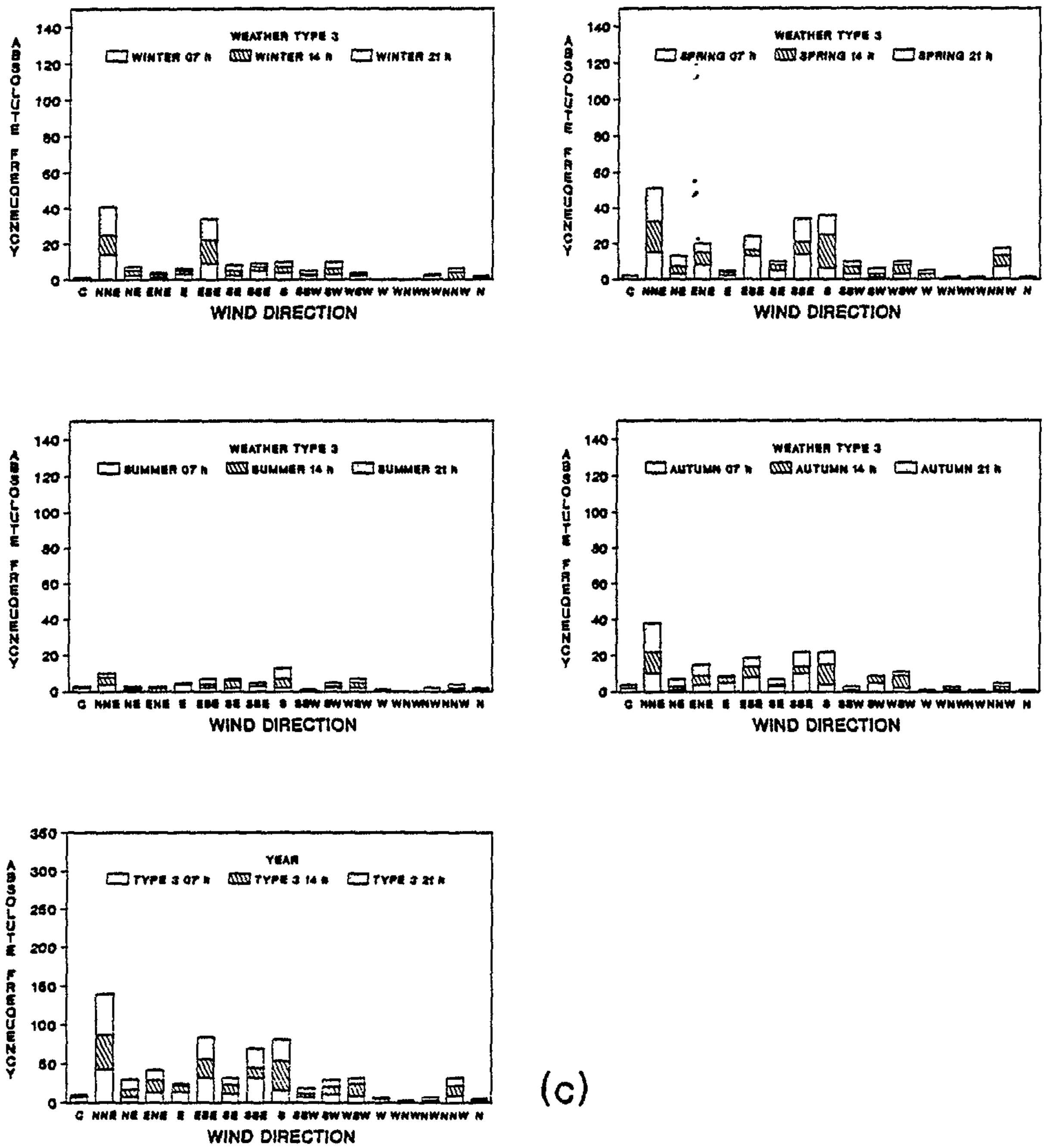






(b)

Figure 2.4.5 b) (cont'd)



(c)

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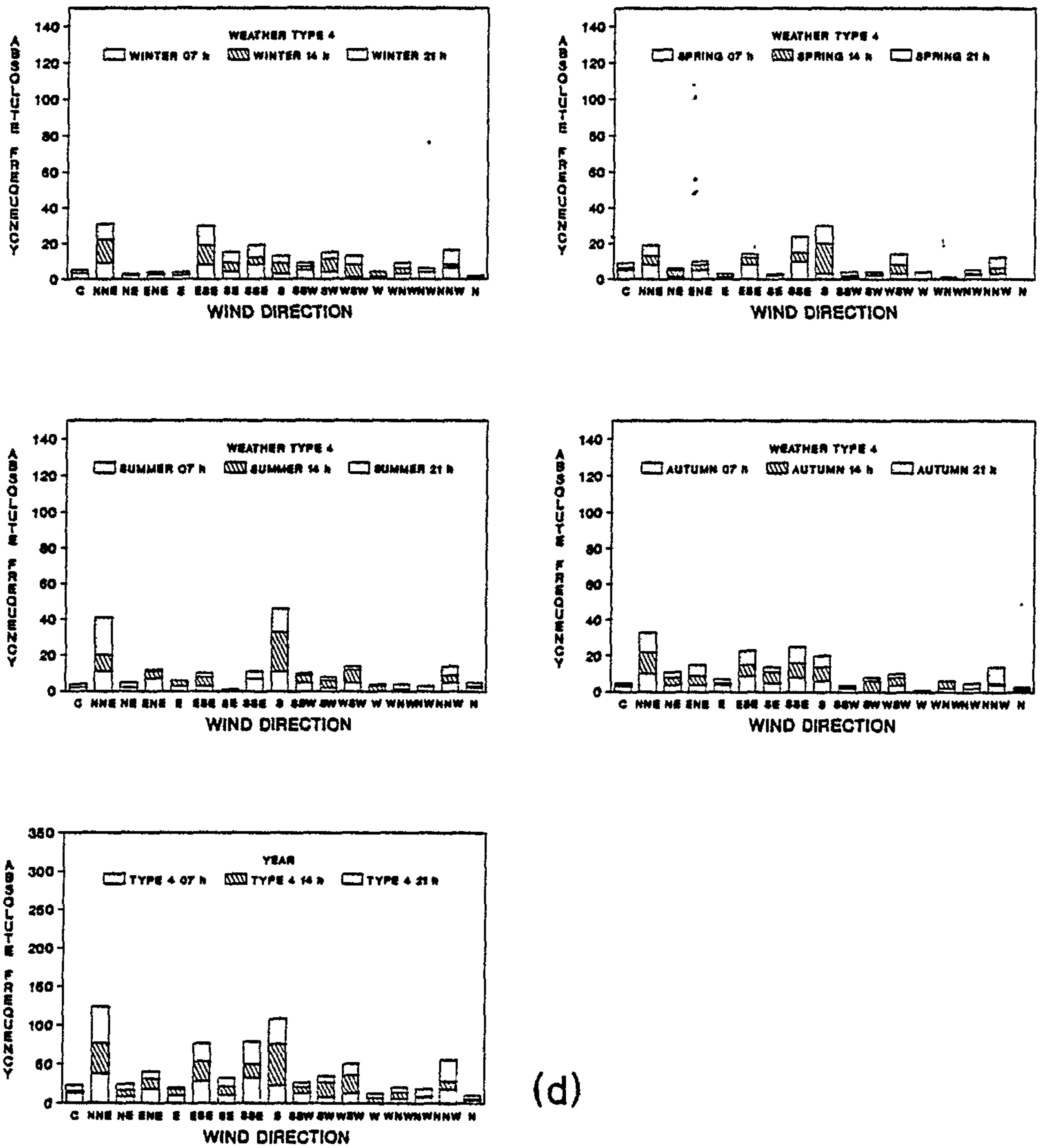

(d)

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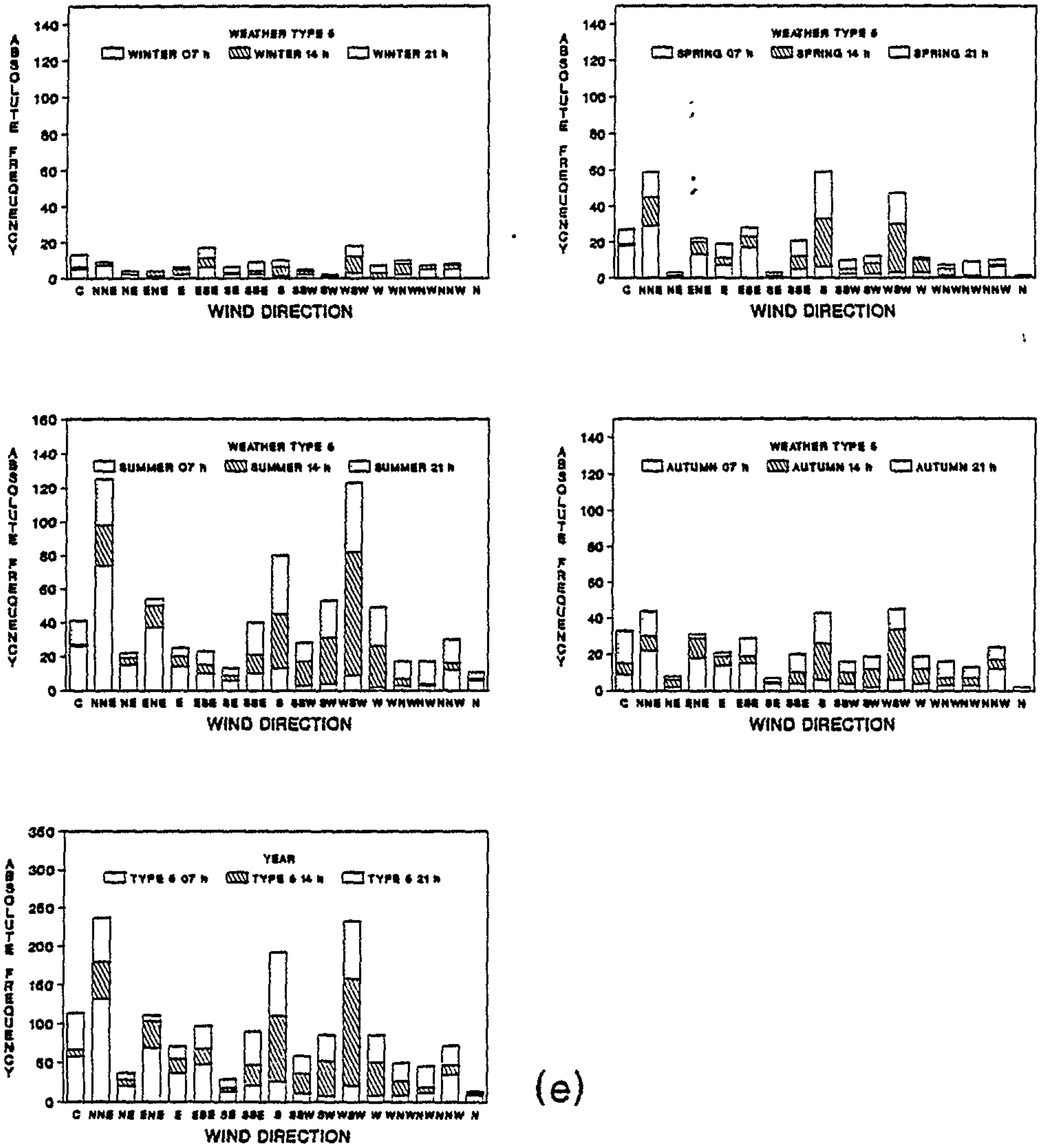

(e)

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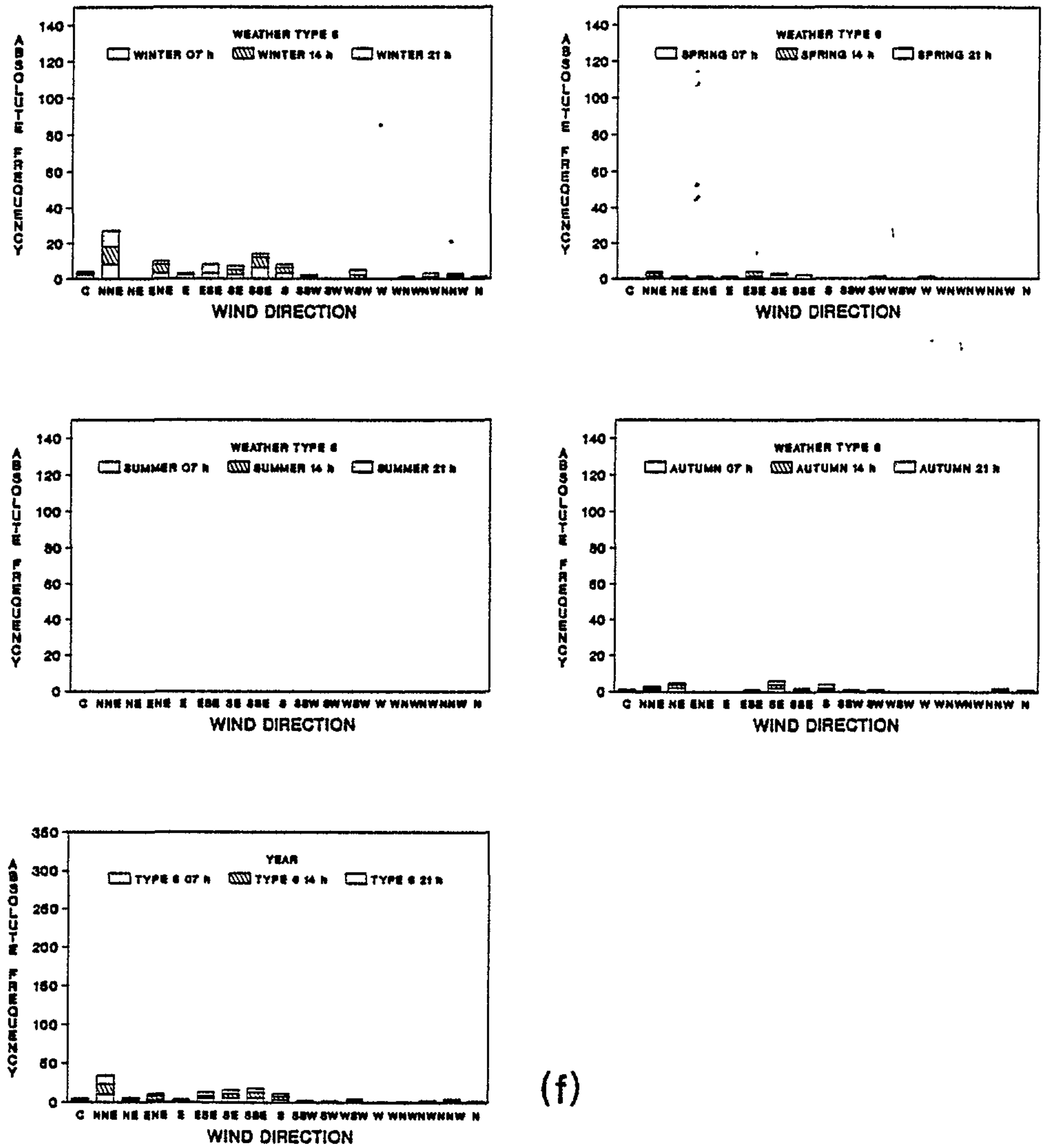
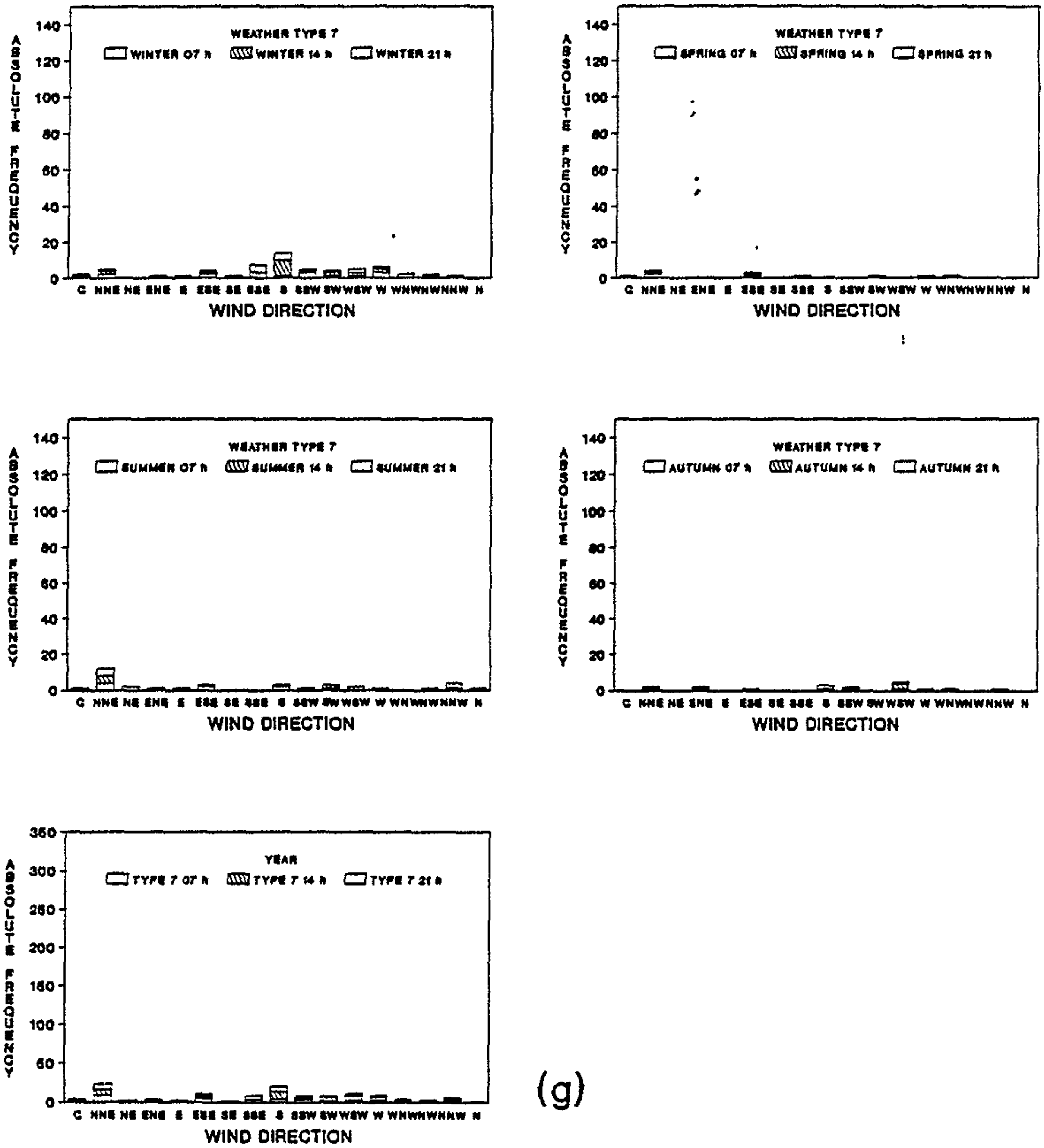


Figure 2.4.5 f). (cont'd)



(g)

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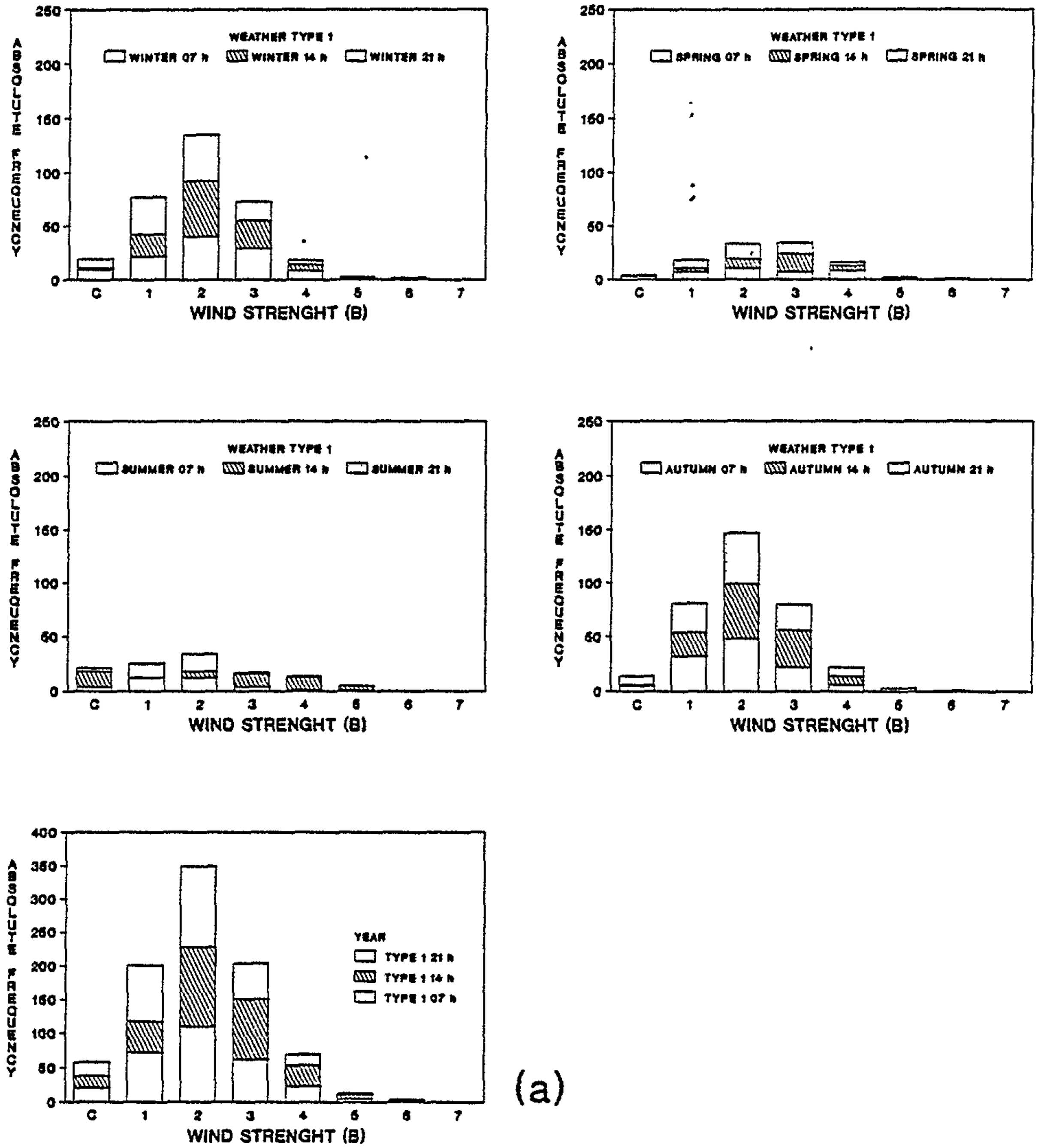
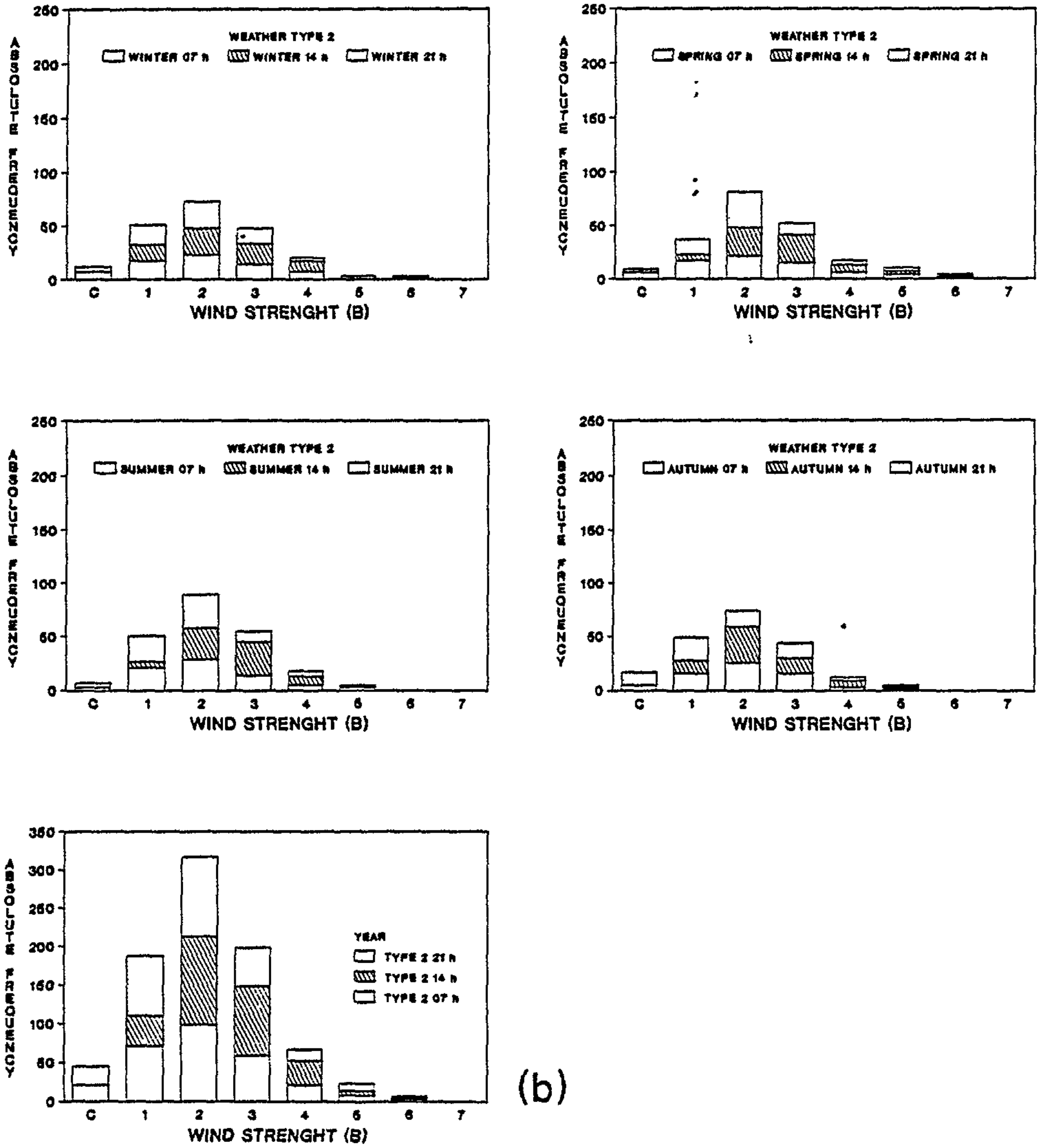


(a)

Figure 2.4.6 (a-g) Seasonal and annual wind strength distributions, in Beauforts, for each weather type (a) Type 1, b) Type 2, c) Type 3, d) Type 4, e) Type 5, f) Type 6, g) Type 7



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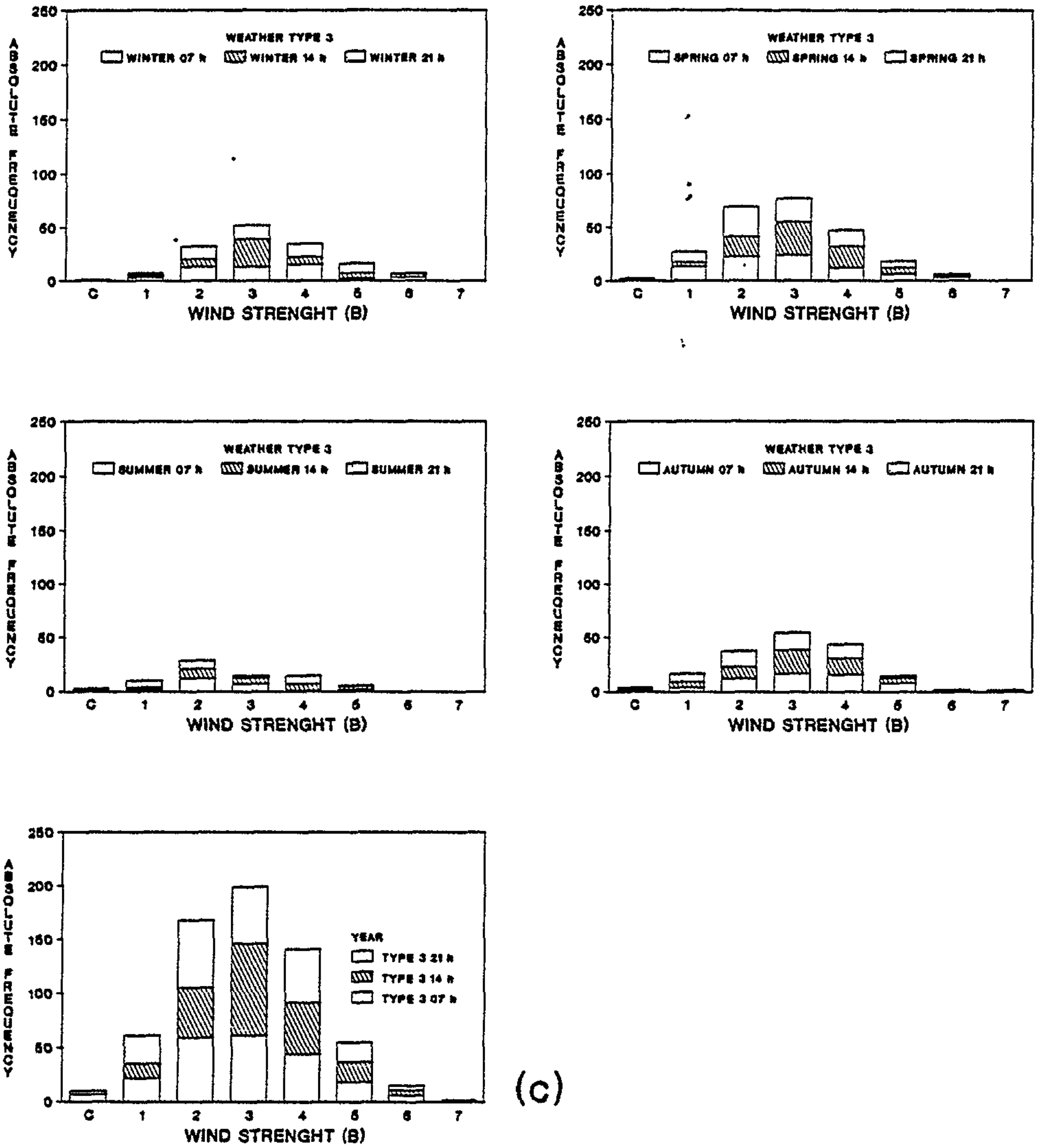

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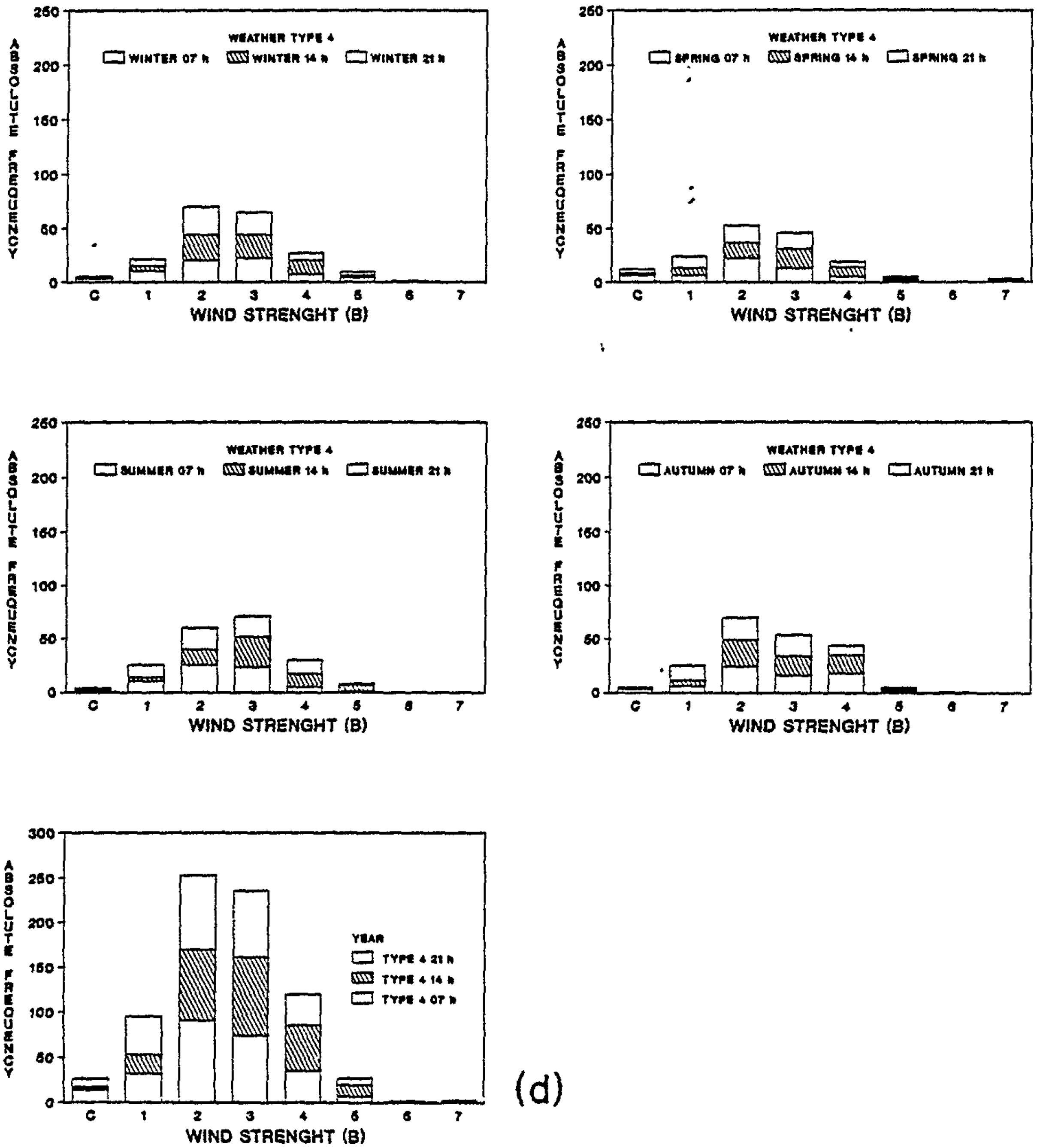

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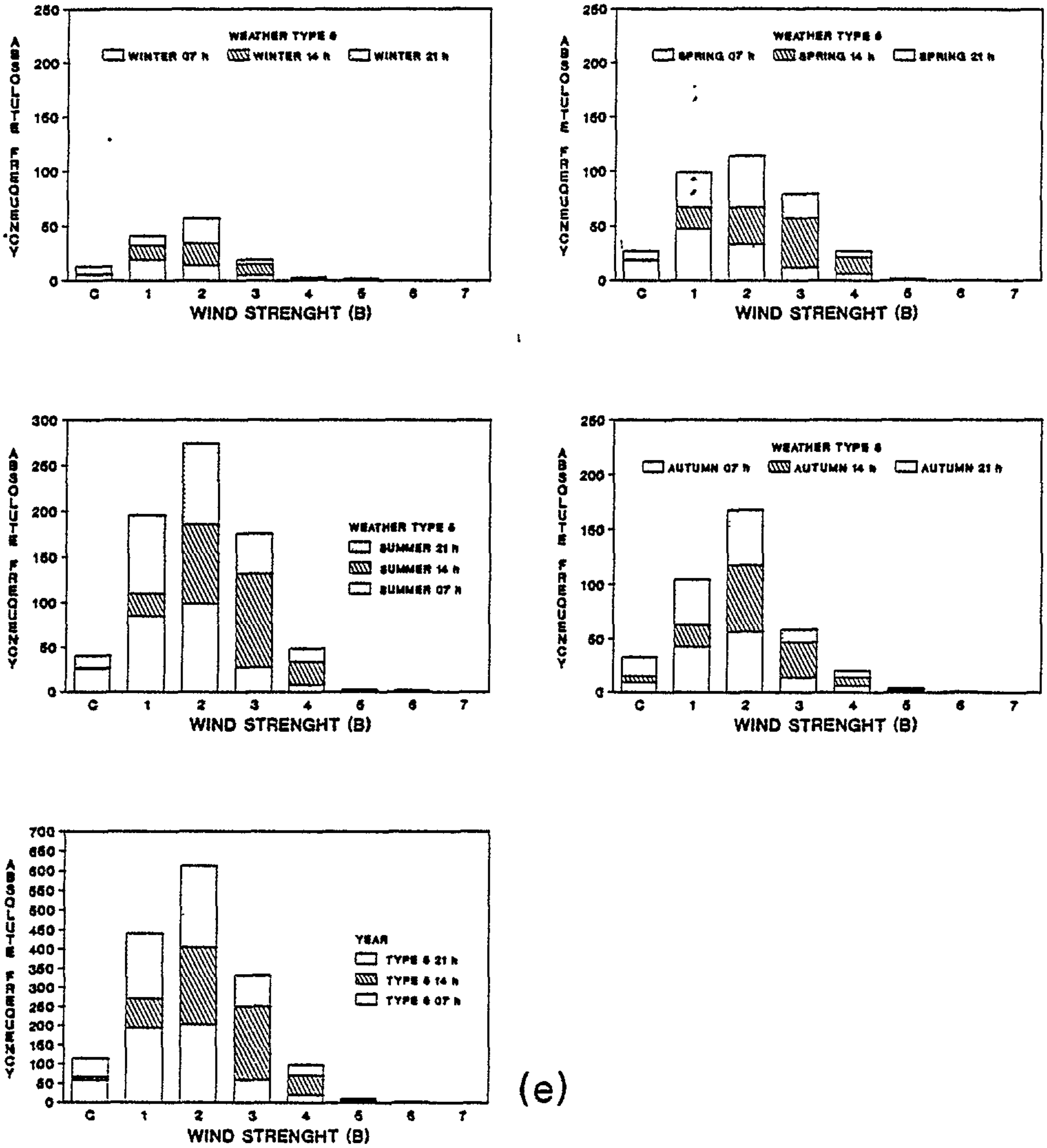

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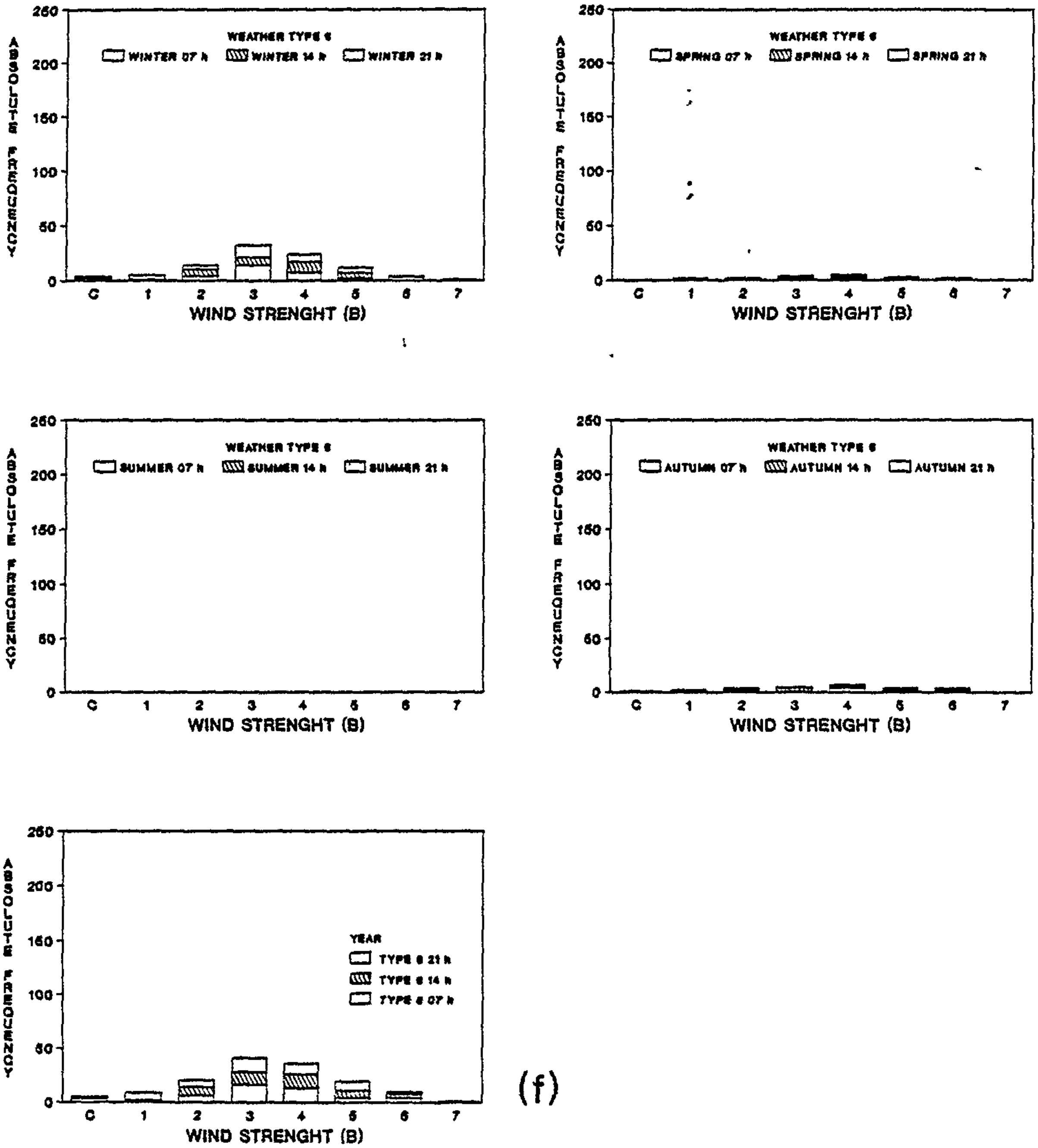

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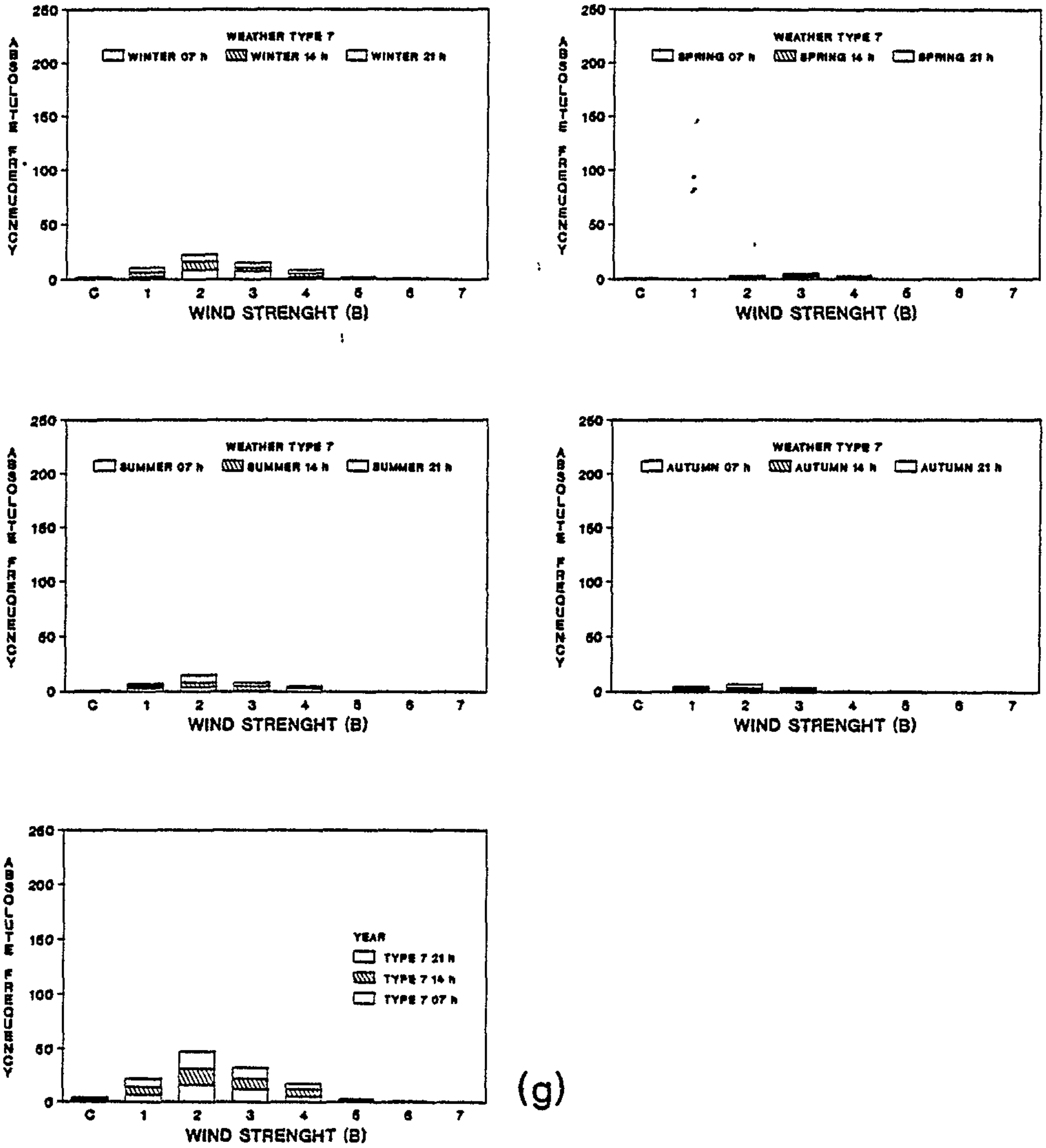

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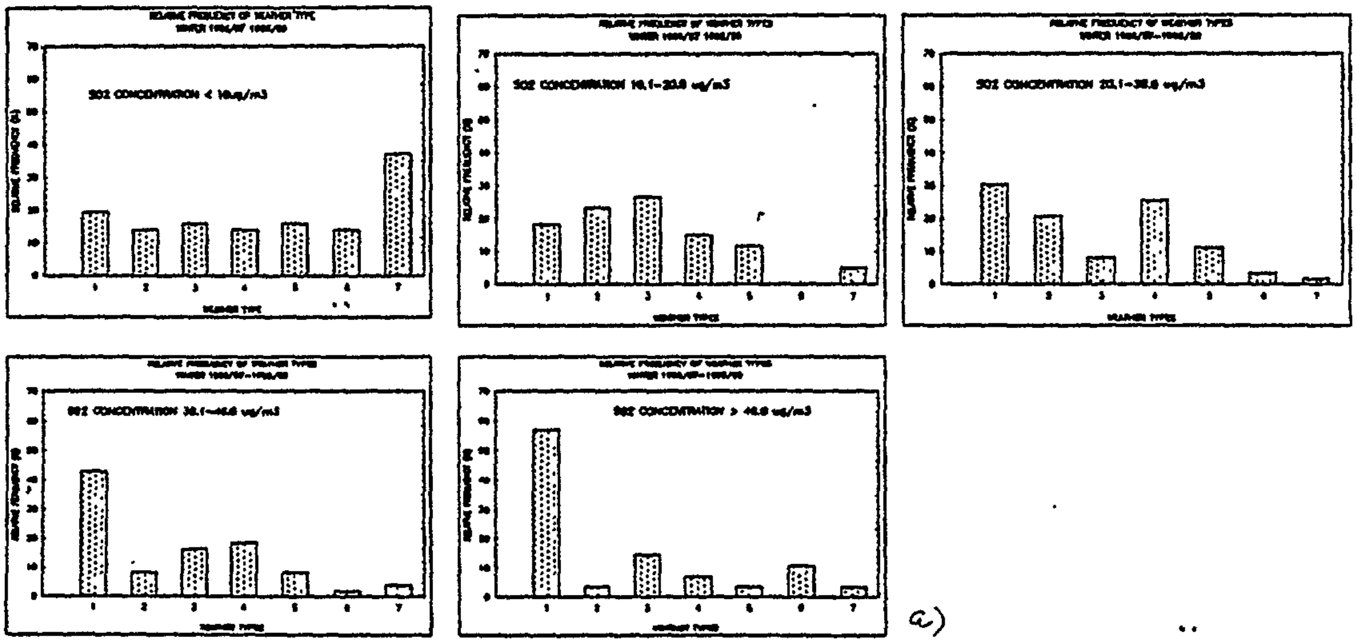
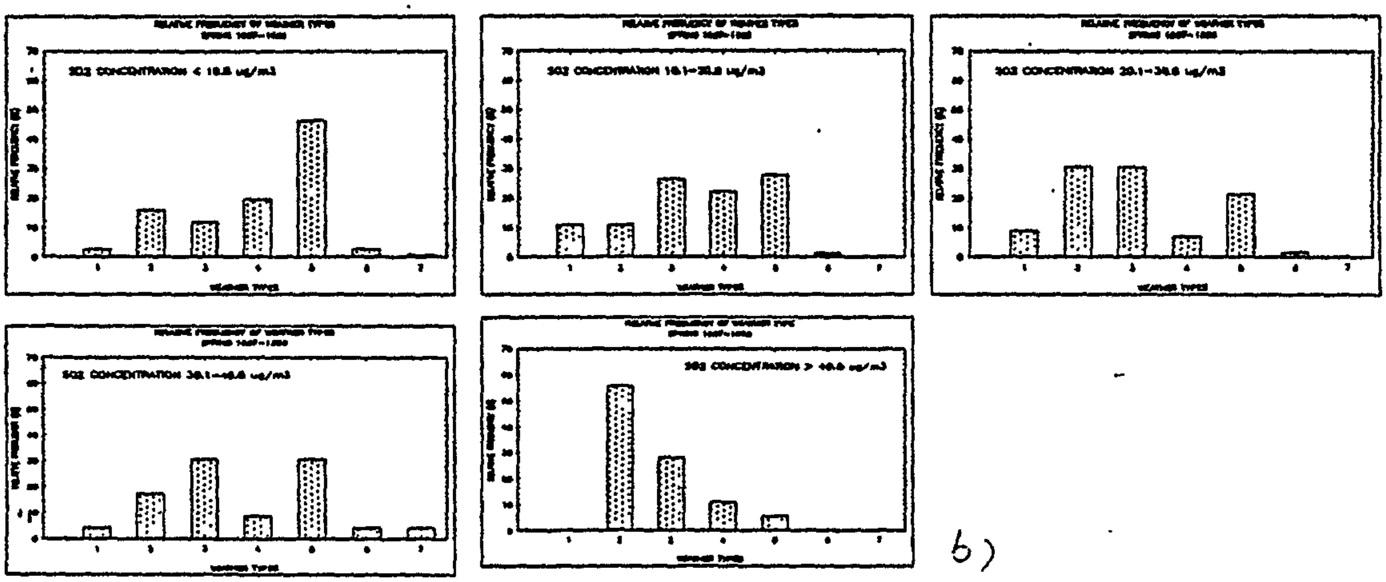


a)

Figure 2.4.7 (a - e) Seasonal (a - d) and annual (e) relative frequency of occurrence of weather types for particular concentration class at Veli Losinj



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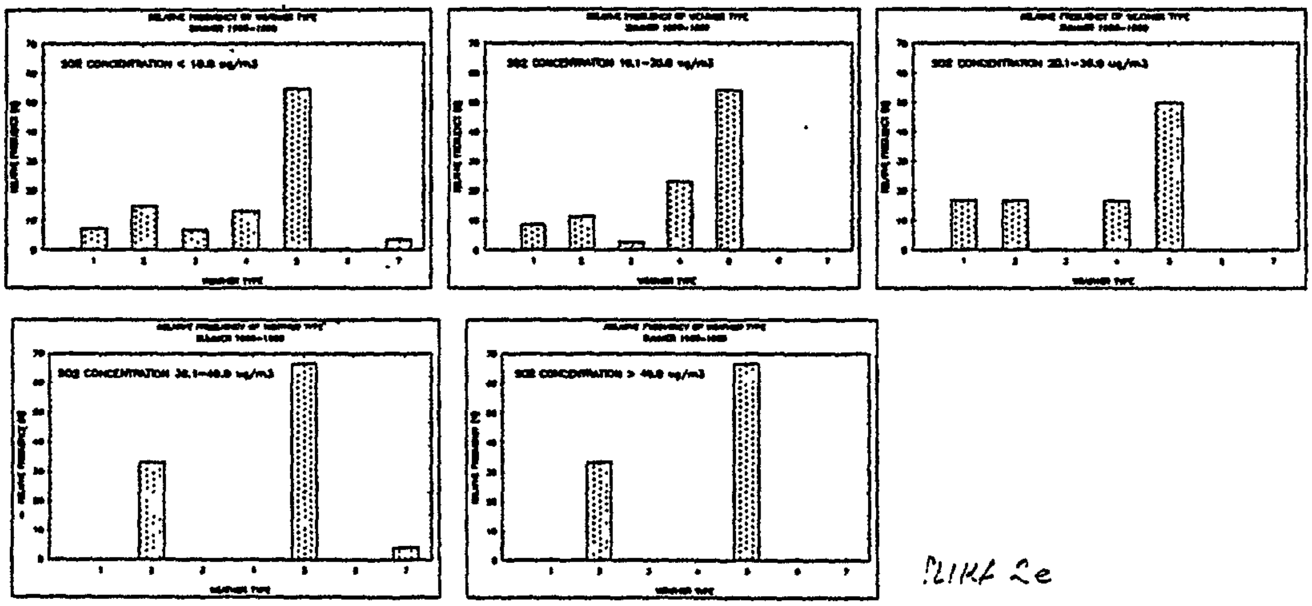

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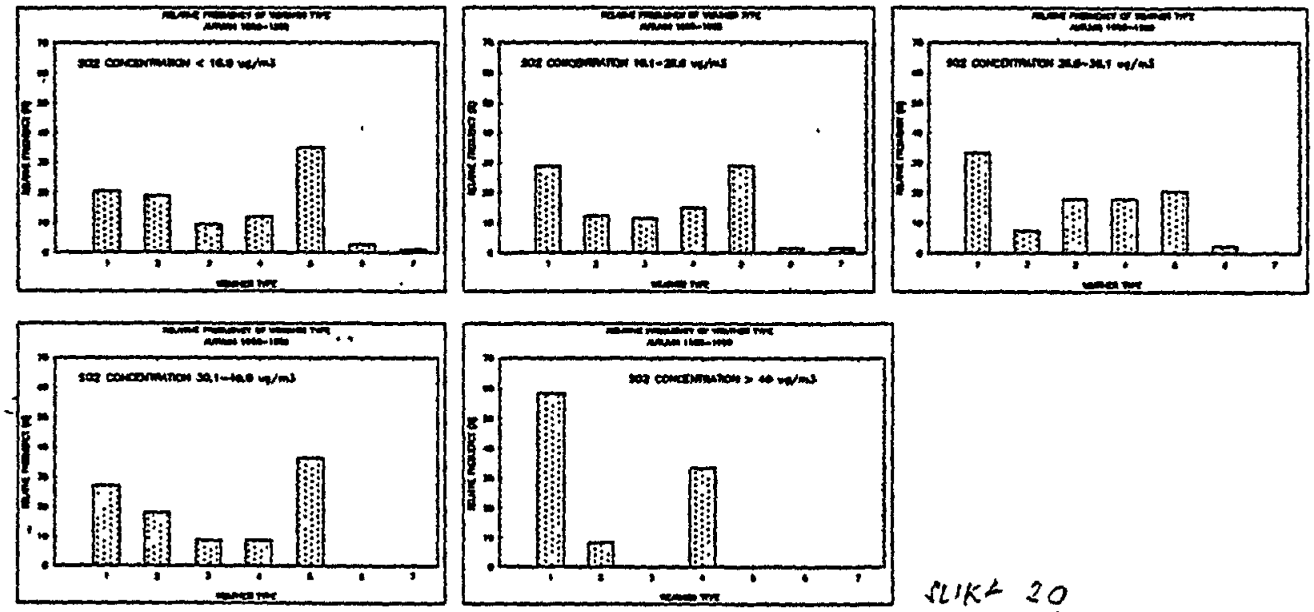

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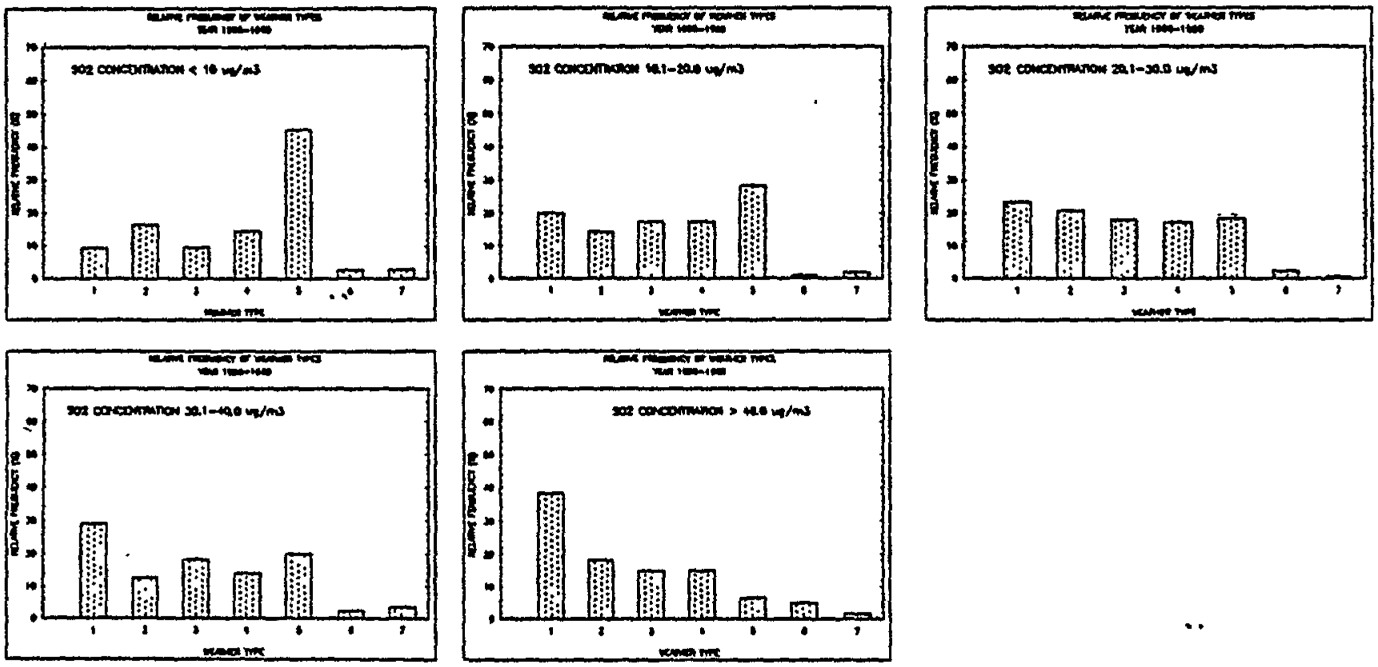

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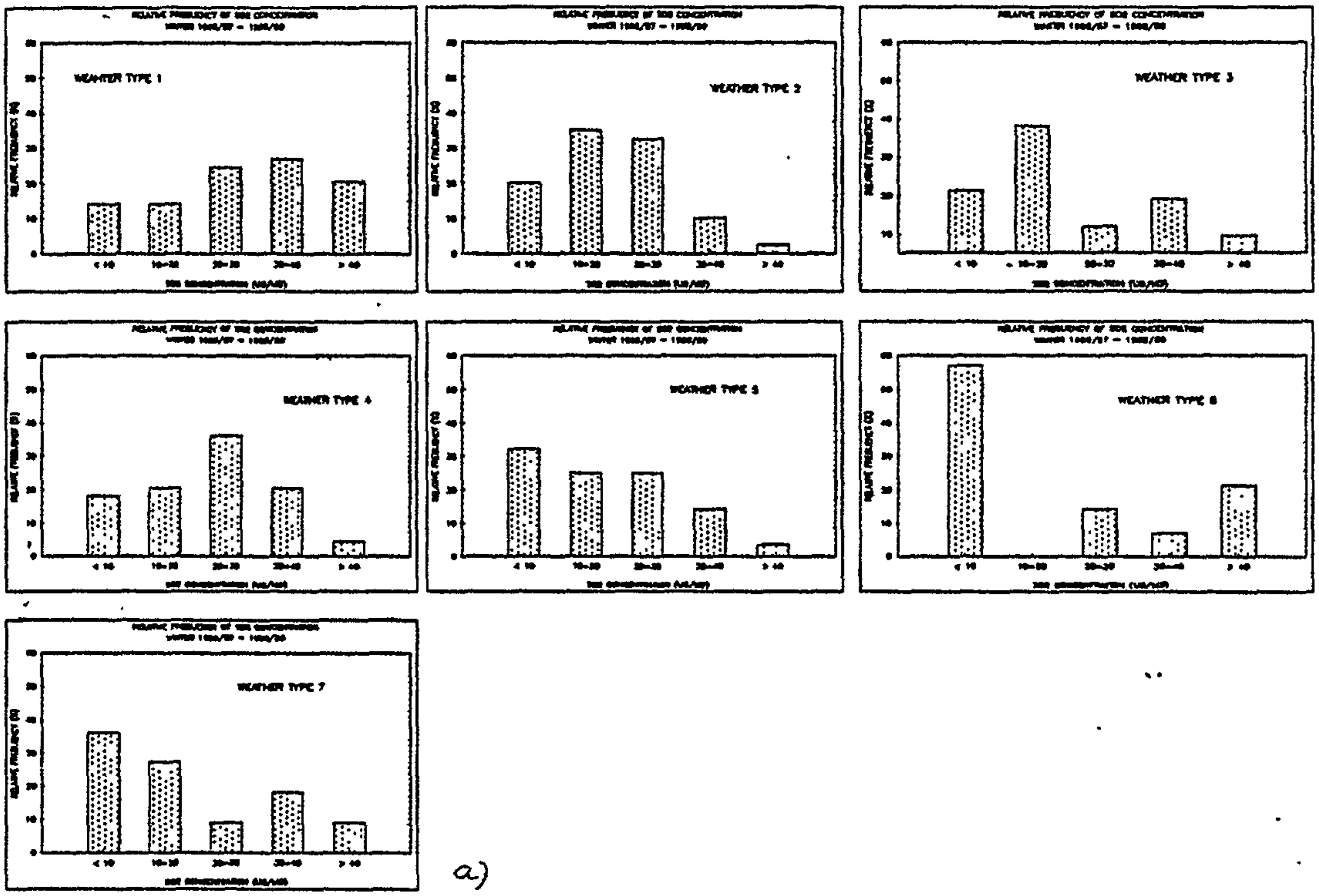


a)

Figure 2.4.8 (a - e) Seasonal (a - d) and annual (e) relative frequency of occurrence of concentration classes for each weather type at Veli Losinj

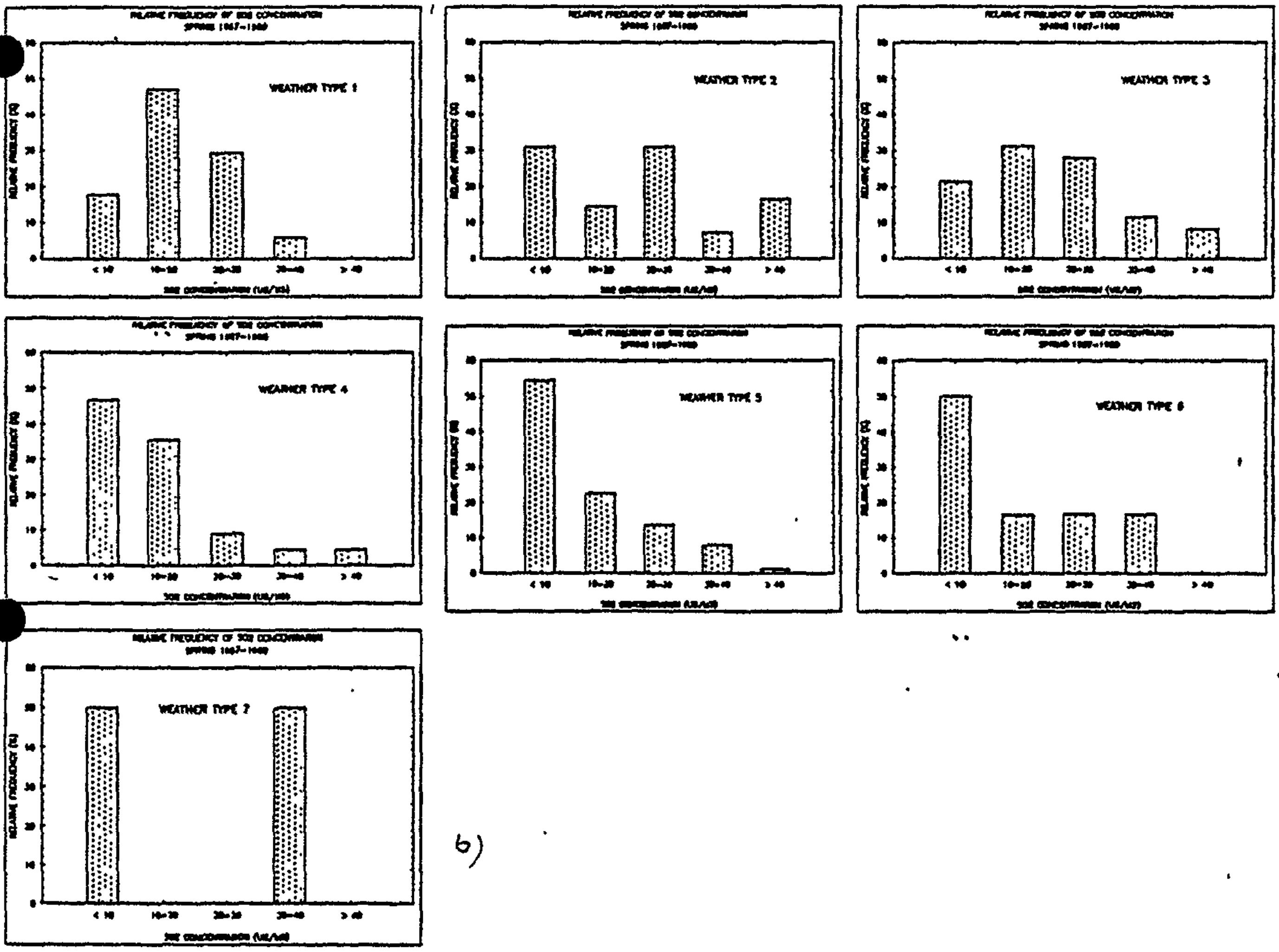


Figure 2.4.8 b) (cont'd)

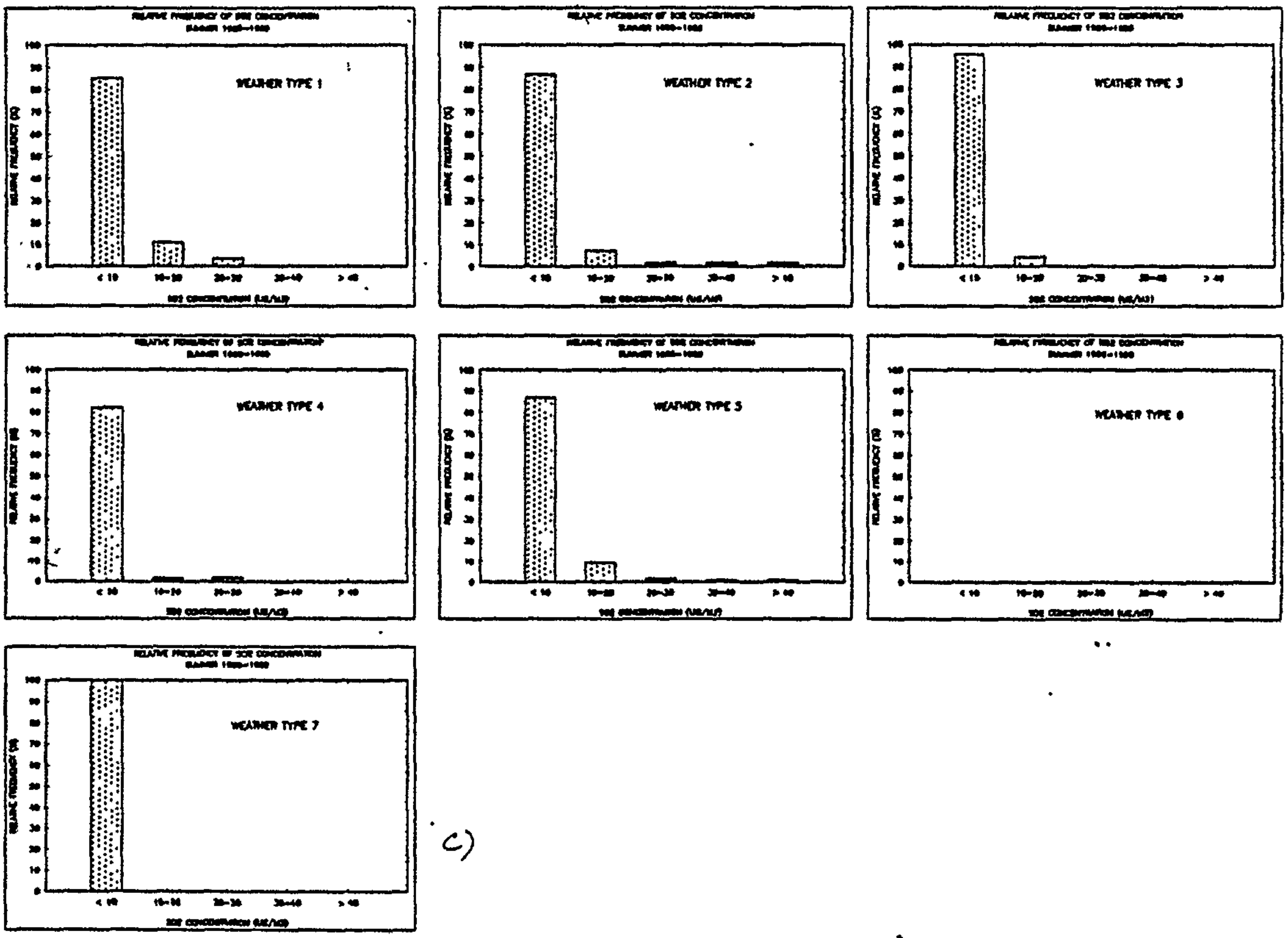
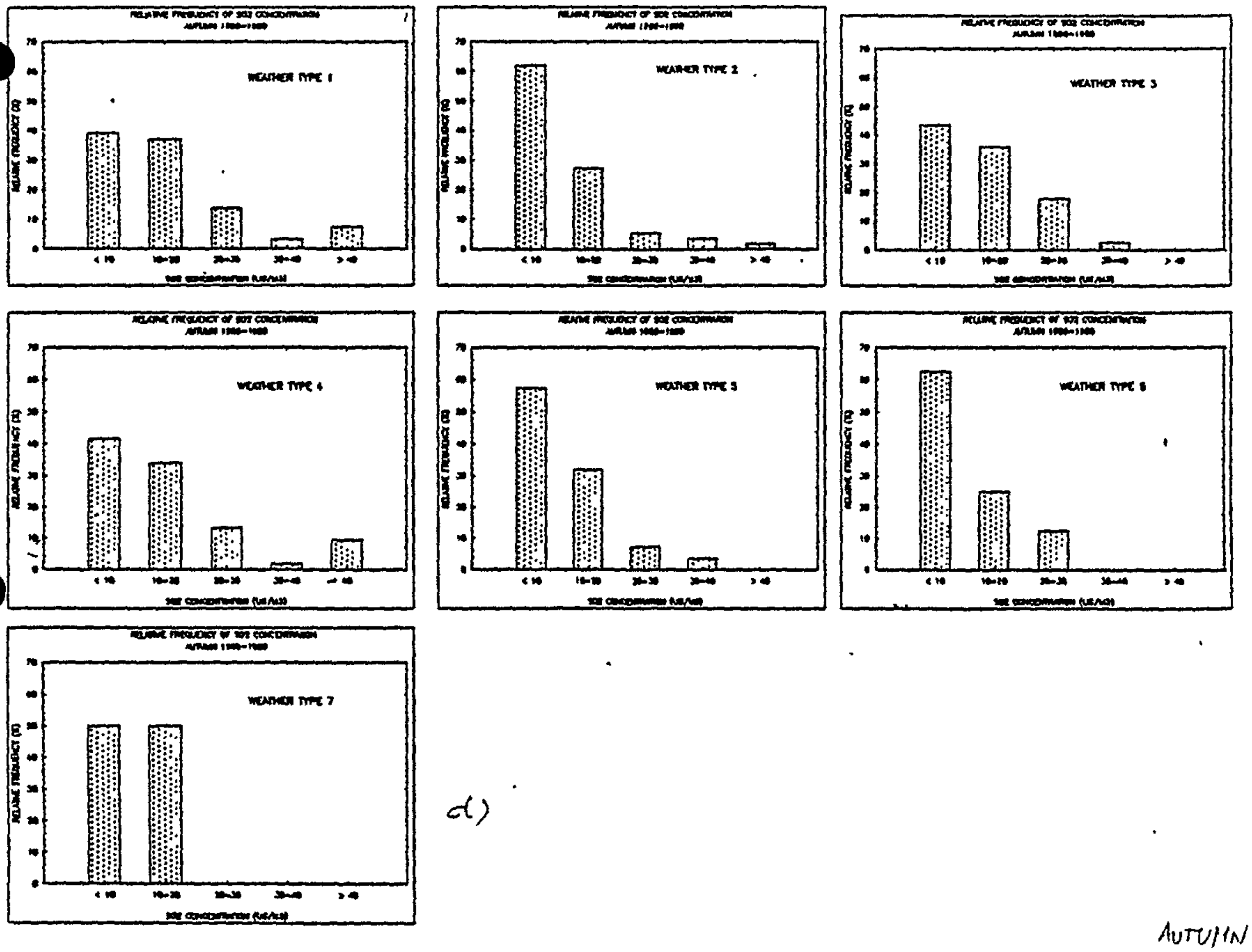


Figure 2.4.8 c) (cont'd)



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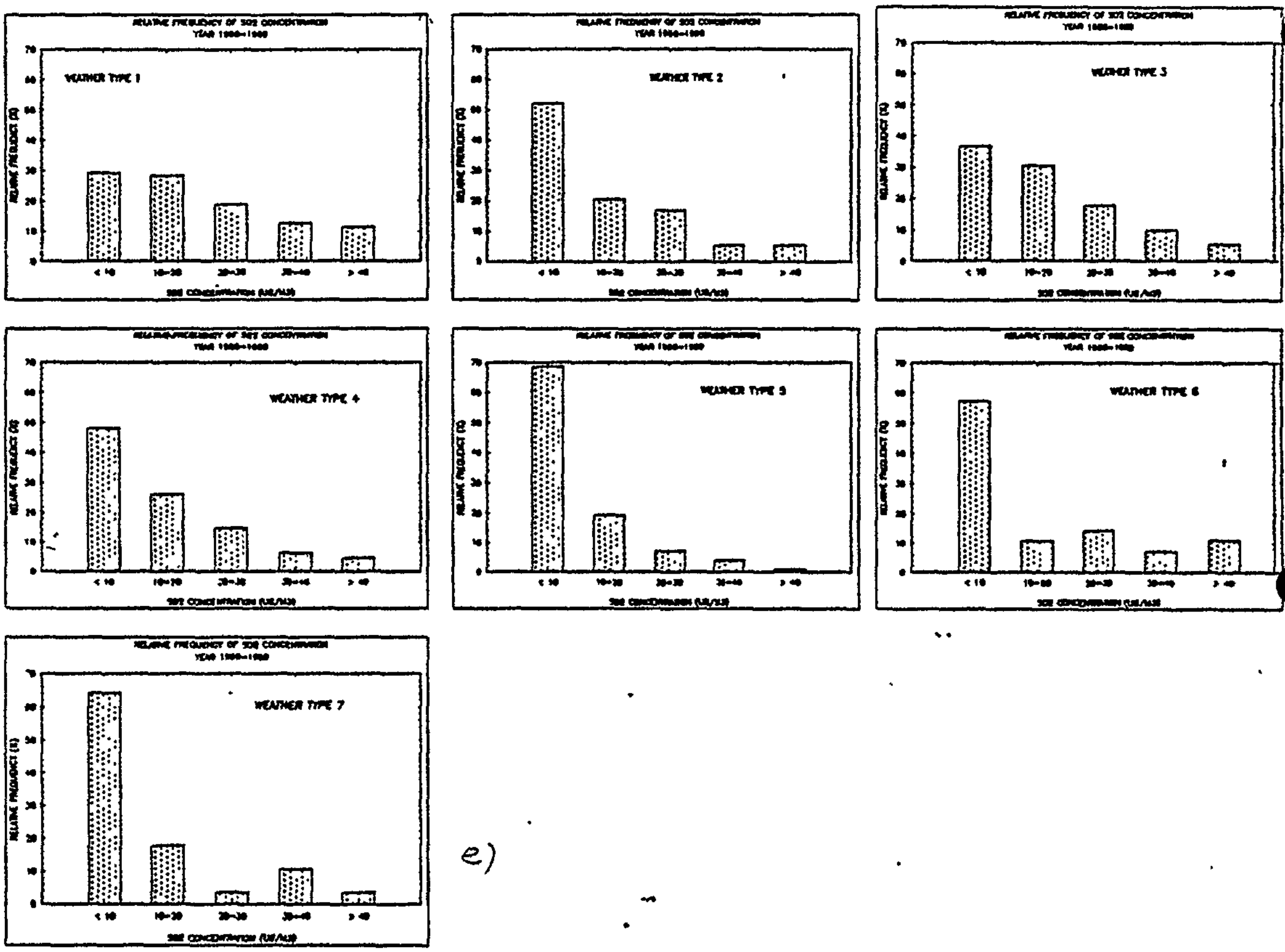

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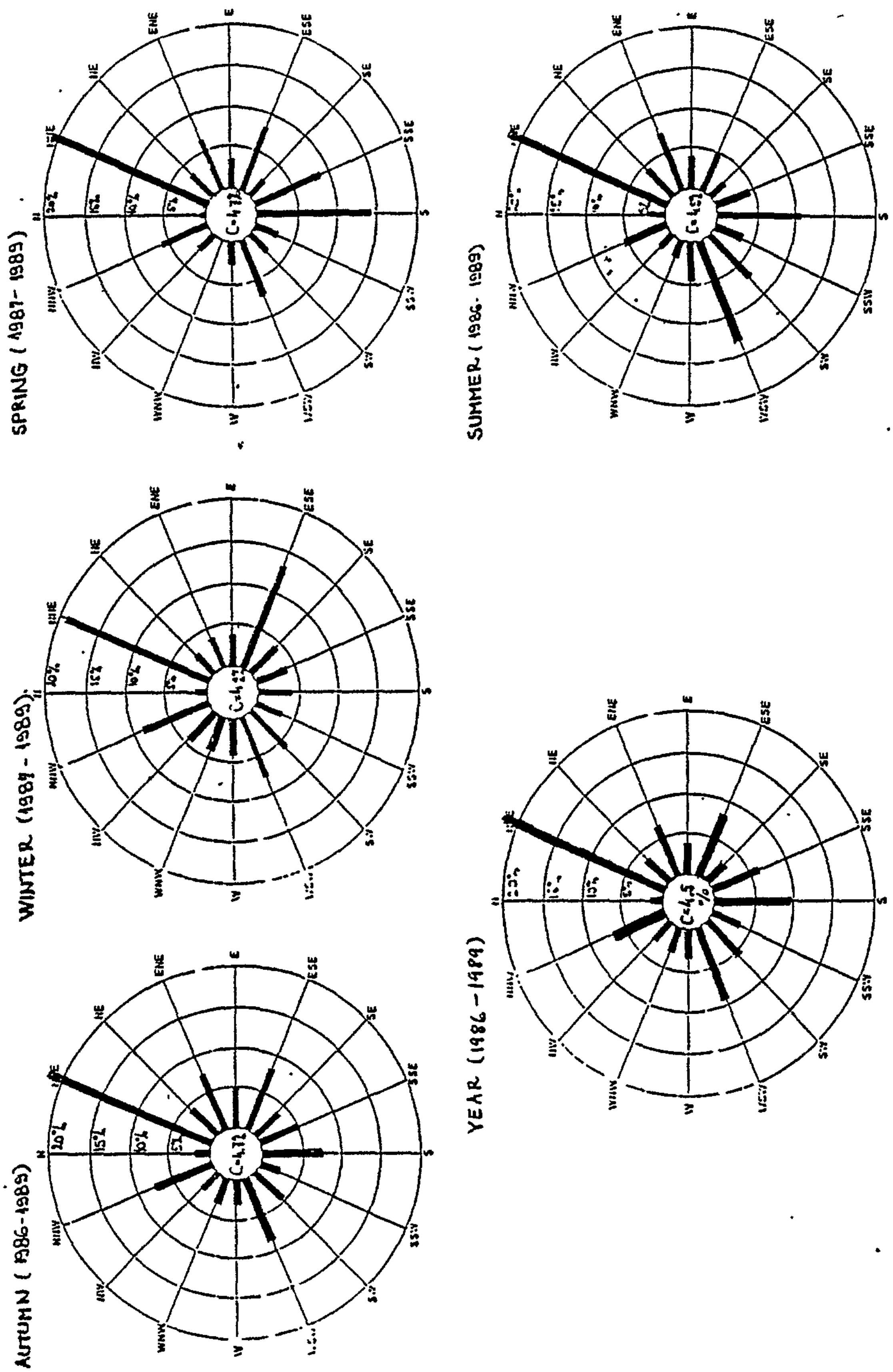

Figure 2.4.9 Seasonal and annual wind roses for Veli Losinj

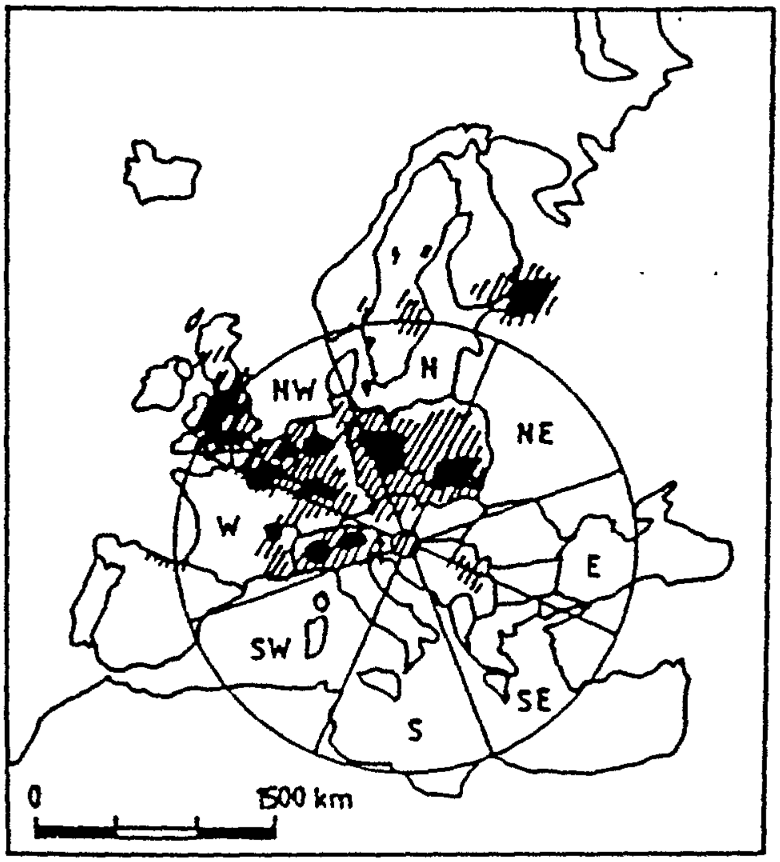

Figure 2.4.10 Main air pollution areas in Europe (Klaic, 1988)

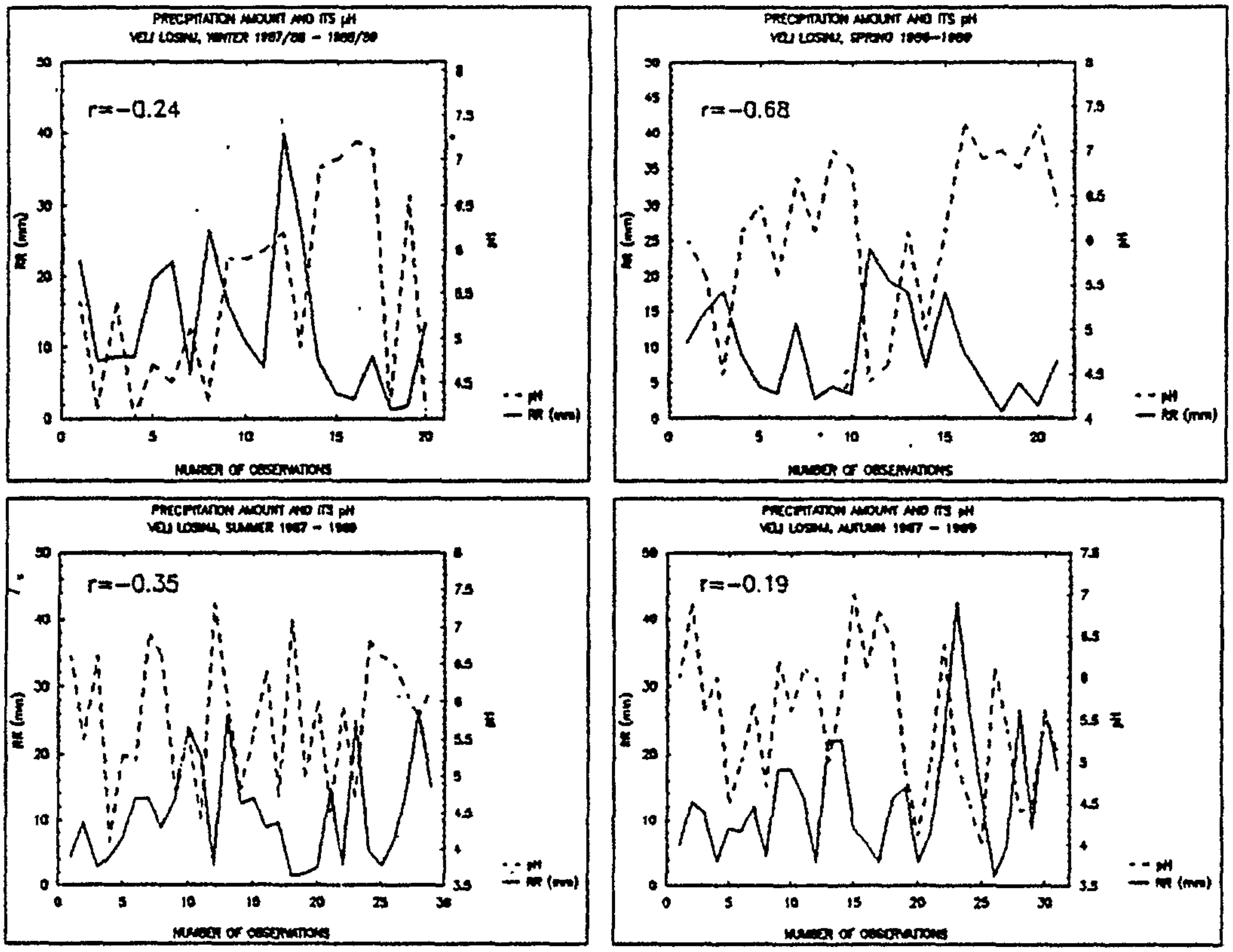

Figure 2.4.11 Precipitation amount and corresponding pH value at Veli Losinj for seasons

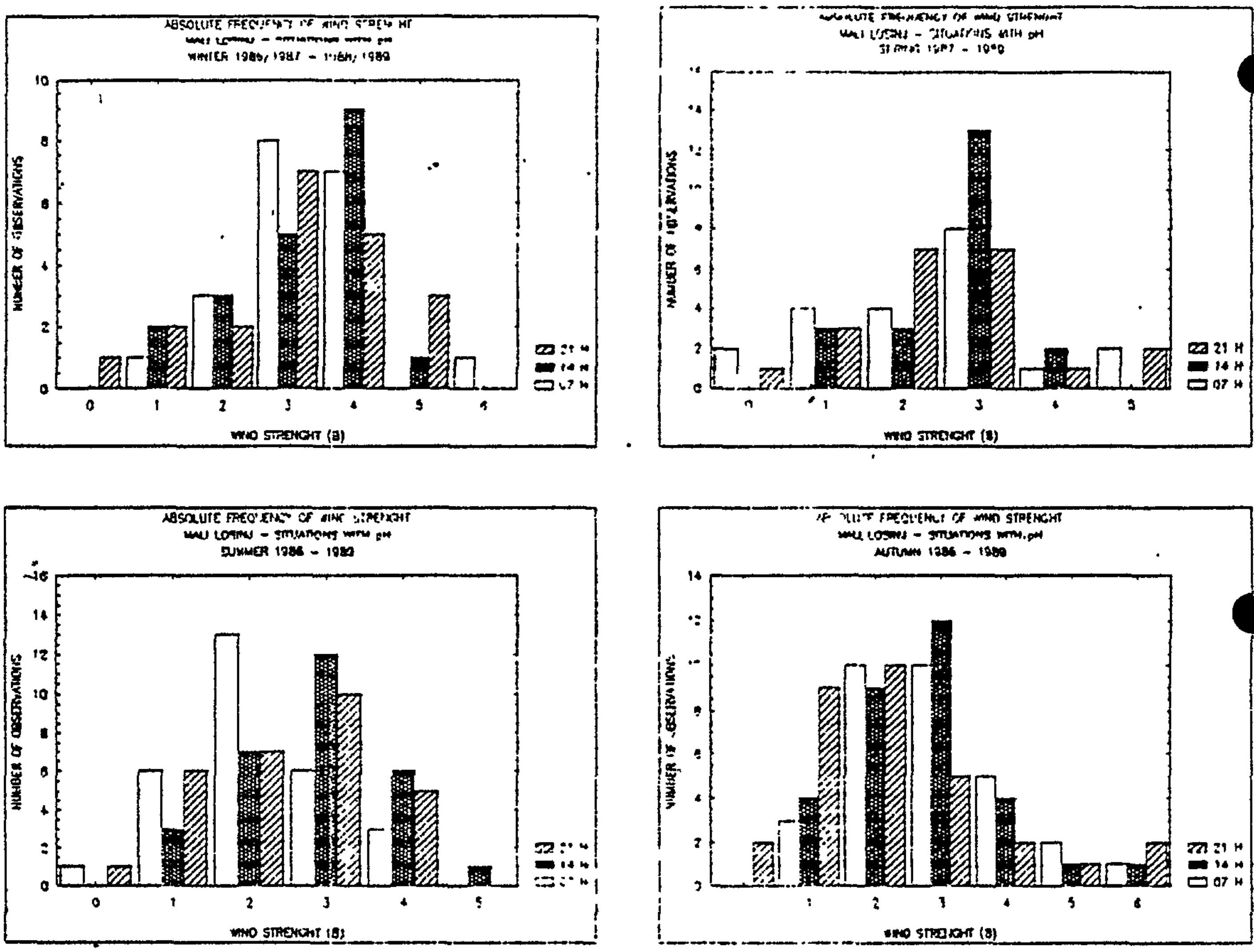

Figure 2.4.12 Frequencies of occurrence of different classes of wind strength (Beauforts) in situations with pH

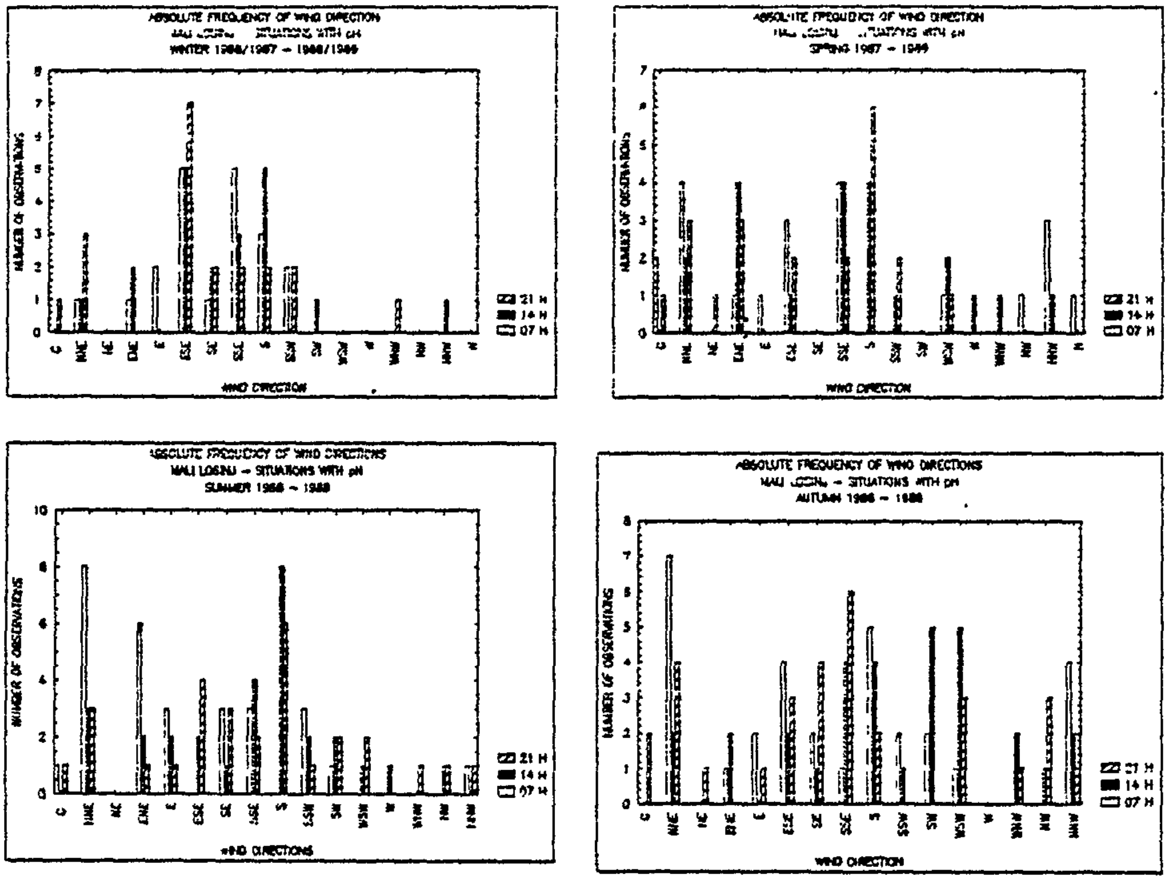

Figure 2.4.13 Frequencies of occurrence of different wind directions in situations with pH

2.5 Natural Ecosystems Including Specially Protected Areas

2.5.1 Terrestrial Ecosystems (Eugen Draganovic)

Past Trends and Present Situation

The Cres - Losinj island group, with a total surface area of 404 km2, ranks among large Adriatic islands. Its direction of stretching being meridional, it presents a quite motley area in ecological sense. In the past these islands had been entirely overgrown with forest vegetation, represented by two basic climazonal types. Deciduous sub-Mediterranean forests cover the northern parts of island Cres, but as well those being situated at more than 250 m a.s.l. This plant cover is relatively well developed, due to the fact it has been less influenced by man. The evergreen oak community is developed on Losinj. In history, the man has for his own purposes altered the natural conditions, so that nowadays beside the authentic forest ecosystems one also finds forest clearings - pastures, as well as agricultural land, and these today cover about 40% of the total island's surface area. Out of the 60% of the area being under the forest vegetation, the evergreen oak community is the best developed, being at certain parts degraded to the state of macchia. This community makes somewhat less than all islands forests, being best developed within Punta Kriza area. As the development of cattle breeding had brought about the degradation of natural vegetation cover, so on the other hand the depopulation of this island area caused the neglect of some agricultural tracts, which are now again being overgrown with the forest vegetation.

Regarding the fauna, islands Cres and Losinj are quite interesting and rich. Their location being in the northern part of adriatic, namely at the very edge of Mediterranean zone, here occurs the mixing of fauna elements belonging to eastern and western Mediterranean. Among all Adriatic islands, Cres is the only one where the mole* (*Talpa europea*) and field mouse (*Apodemus flavicollis*) live. The area also abounds with lizards, no less then 12 species living in the area. So on Cres, as the only Adriatic island lives the common wall lizard (*Poderas muralis*), which is otherwise spread out all over the European continent. Likewise, exclusively on Cres is where the both species of green lizards live within the same area: the Balkan green lizard (*Lacerta trilineata*) and the green lizard (*Lacerta viridis*).

Although the Cres is, apart from Vransko jezero and some pools, a waterless island, one finds in the area na less than 7 species of amphibians and among these it is worth mentioning the agile frog (*Rana dalmatina*), yellow-bellied toad (*Bombina variegada*), as well as the smooth newt (*Triturus vulgaris meridionalis*), which live along the Vranskojezero.

The ornithofauna is in this island group very rich and it should be particularly stressed that on the Cres island area there are two colonies of the griffon vulture (*Gips fulvus*).

The largest predator living on islands is the beech marten (*Martes foina*). The black rat (*Rattus rattus*) is an animal arriving to the islands together with the man and had spread out all over the territory and is now the most dangerous predator for many species living on the islands.

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* (*Talpa europea*) and field mouse

Specially Protected and Registered Nature Spots

Viewing from the standpoint of nature protection, the island group Cres-Losinj is together with the adjacent lesser islands, a relatively diverse area. Despite this fact, only two localities are under the statutory protection pursuant to provisions of Nature Protection Law (Official Gazette of Croatia 54/76). A greater number of interesting and valuable areas had been registered in the course of past years and for some of these it had been proposed to be put under a special protection, but that was never formally enforced.

The special reserve is an area in which one ore more nature's elements are particularly prominent, while it possesses a distinct scientific significance and purpose - in accordance with IUCN, category I.

1. The area between the Fojiska and the Pod Predoscica coves - the special ornithological reserve. The steep part of Cres island, facing east, is an important nesting place of griffon vulture, a bird being endangered throughout the entire Europe and is therefore on the list of animal species facing extinction. At present on precipitous rocks nests the population which is for the time being stable and, together with the neighbouring locality, more to the south, some 25 pairs.

2. The area between the Mali Bok cove and Koromacno cove - the special ornithological reserve - nesting place of the griffon vulture.

Both these reserves have been enacted by the Decree of the Assembly of the Cres - Losinj Municipality in 1986.

As the griffon vulture Builds nests on precipitous rocks, a possible change in the plant cover resulting from the change of climatic conditions under consideration could not influence this population to any greater extent. The main danger for survival is the lack of food. The decreased number of sheep being bred on islands causes a fall in number of carcasses on which these birds feed. It could be therefore presupposed that the increase in temperature of air and sea, as well as raising of the sea level, will not significantly influence the survival of these populations and reserves on Cres.

Following the inspection of the Cres-Losinj region, the following land spots have been registered for protection.

Within the category of prominent sceneries, meaning a natural or cultivated area of higher aesthetic value, which could be characteristic for particular region - according to IUCN, category V, the following localities have been foreseen for protection:

1. Sv. Vid with Merag and Kruscica coves

In geomorphological sense the peninsula is specially interesting, being at its northern side steep, partly rocky, sides reaching up to 300 m, such as near Merag, while in the eastern direction occur cliffs. The south-eastern side stands out by the picturesqueness of Tarej Point behind which is located the cove Kruscica. Among rocks in the northern part there is geomorphological phenomena of Meraska jama (Merag Cave). The northern coastline above the Merag cove is covered with Eumediterranean vegetation, which continues into the pubescent oak forest belt with oriental hornbeam. The macchia covers the coastal belt from Lupeska cove to Kruscica, on top of which a smaller area of pubescent oak forest has been preserved.

2. The Lubenice area

A very picturesque human settlement of rural appearance since as late as the times of antiquity, located on the steep western coast of Cres. The steep slope below the village contains characteristic scenes with poor vegetation, falling down into the sea. The entire Lubenice complexus an unique landscape and should be preserved as such.

3. Island Unije

Largest in the group of Losinj islands. A level area of 300 ha at its western side is covered with loess. At the island's northern part nestle sea gulls and Alpine swift, giving thus the island an ornithological value.

4. Island Susak

This island occupies an exceptional place among all the Adriatic islands. Deposits of fine Pleistocene sand - loess, some tens of metres thick, overlie the limestone substratum and this gives the island unique natural and landscape features, the very top of the island, being 98 metres high, is also covered with this sediment. The loess has at the same time stipulated the economic structure of the island, which at times past used to be entirely under vineyards and reed, which prevents the eolian erosion. As a result of the island's depopulation, many vineyards are now neglected and overgrown.

5. Punta Kriza

The farthest south-eastern part of island Cres is over-grown with compact macchia, with enclaves of agricultural crops around villages and hamlets. In this area predominate lower zones of gentle limestone ridges and plateaus, abounding in lesser and levelled out karstic forms. Vegetationally, this part of Cres is analogous to the eastern side of island Losinj. In Deeper soils there are pubescent oak compounds, while the lower positions are covered with macchia. Adjacent to the Punta Kriza village there is a largish culture of Aleppo and black pine.

By the inspection of Cres-Losinj region, the following areas have been registered in terms of Nature Protection Law as areas which should be protected in the special reserve category:

1. The Forest Vegetation Reserve - the Forest Niska on Tramontana

Within the zone of pubescent oak forest in the northern part of Cres there is a number of preserved localities where chestnut trees occur, the majority of these growing in the forest Niska on Tramontana. Some lesser groups are also to be found within the Merag forest area. The presence of this authentic natural variety of chestnut points to the analogy of this area with the neighbouring Opatija Coast. The chestnut is in carstic ecological conditions an exceptional phenomenon.

2. Botanical reserve on Veli Osir Islet

This islet with surface area of 40 ha and being situated at the north-eastern side of the Losinj island, is entirely overgrown with phoenician juniper (*Juniperus phoenicea*) in complete canopy and density, which is an unique case in the entire Adriatic region and should be permanently preserved without changes.

3. Special Hydrological Reserve Vransko Jezero

One of largest hydrological phenomena of our karst. Data on the living world in the lake will be listed in the paragraph 2.5.2.

In the forest park category it is foreseen to protect the forest on Cikat peninsula. This is the largest and finest forest of Aleppo and Dalmatian pines, being positioned on the line between Mali and Veliki Losinj, between the Kriska cove. The forest had been planted at the end of last century in the zone of degraded climazonal forest of evergreen oak. The finest part of the compound covers the Cikat peninsula and the Sv. Ivan hill over Losinj.

Expected Effects and Most Vulnerable Systems and Activities

Climatic changes envisaged by the scenario could to a certain extent reflect themselves upon the natural vegetation cover. As the temperature increase is generally foreseen, one can suppose that there will be an extension of the area which is presently under the evergreen Mediterranean vegetation at the cost of sub-Mediterranean communities. Evergreen elements of the sub-Mediterranean zone can endure warmer weather, which is beneficial to them, as opposed to sub-Mediterranean deciduous communities which do not favour the soil desiccation and the intensified evapotranspiration. One can therefore expect that chestnut forests, which here find themselves at the southern margin of their range, will be most endangered and disappear from the northern part of island Cres in course of time.

It can also be assumed that in the animal world of islands the eastern Mediterranean population will expand at the cost of mesophyllic ones. Considering that the animal world demonstrates the property of adaptability, one need not to expect more significant changes in the fauna composition of Cres-Losinj Archipelago.

The specially protected nature's spots, nor those foreseen to be protected will not be affected by the envisaged alterations, except where the landscape is concerned, because the envisaged sea level raising will cause over-flooding and submergence of certain low coastline parts, such as on Susak, Ilovik or at Punta Kriza.

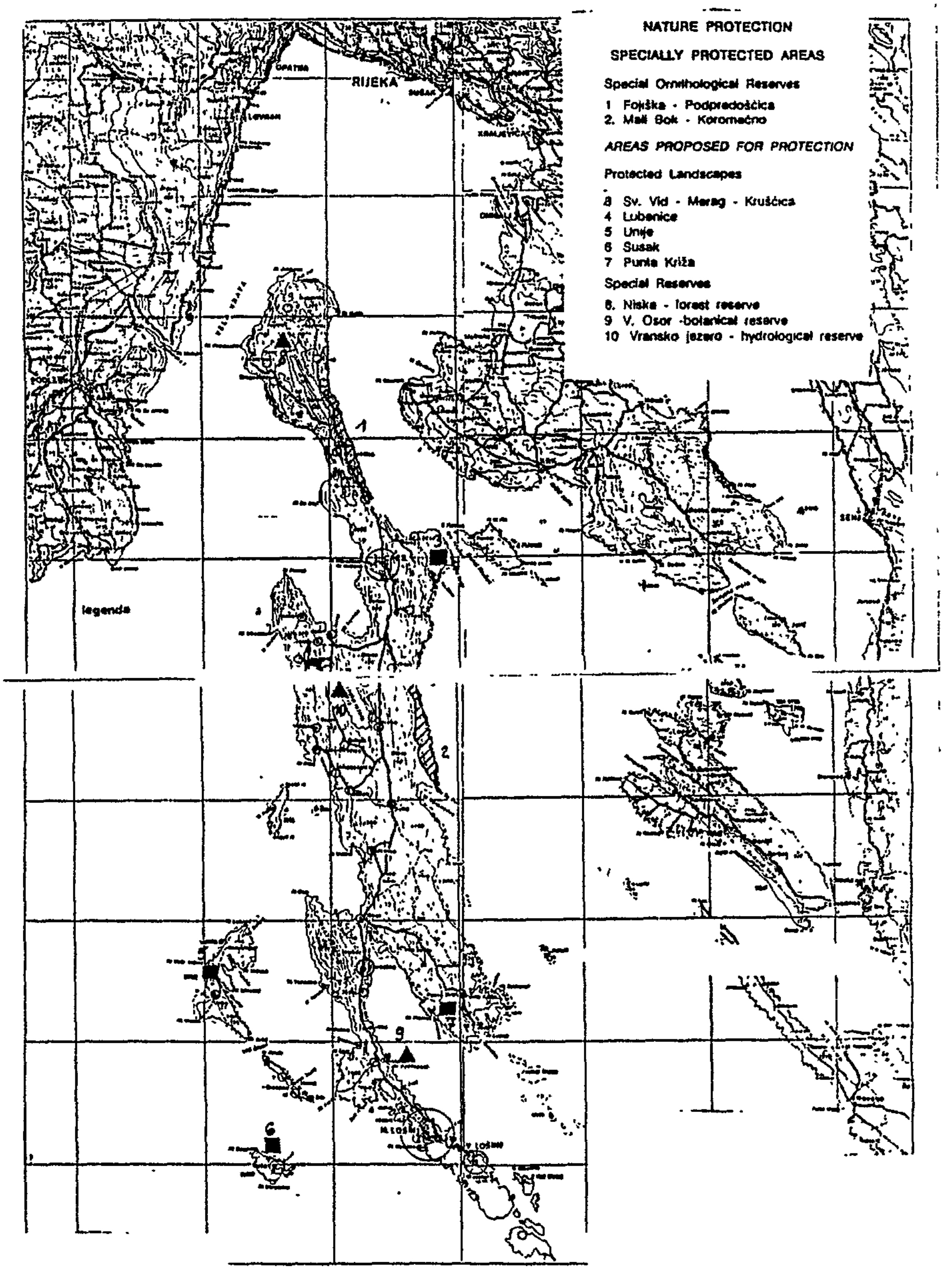


Figure 2.5.1 Specially protected areas and areas proposed for protection

2.5.2 Freshwater Ecosystems

The predominant freshwater ecosystem of the Cres-Lošinj group of islands is the Lake of Vrana on the Cres island. The coastal springs and vruljas (submarine springs) are of a minor significance. When these springs are concerned, we may only record the sites and try to estimate the rates of discharge. That is the reason why these springs are not under an, otherwise, thorough vigilance of the regional water management authority. Because of that, there are no accurate data, at least, to estimate the water quality of these springs.

Basic data about the Lake of Vrana, about its genesis and hydrological problems are given in chapter on the hydrosphere. Lake water quality data, existing and planned protection measures and forecasts of possible consequences due to climatic changes will be shown within this chapter.

The physical, chemical and sanitary analyses of the lake water indicate that this water belongs to the first class of the drinking water standard. A slightly lower quality was recorded in autumn, i.e. at the end of the late summer-autumn dry season, when the bacteriological analyses put the water into the second class of the drinking water standard. To illustrate the physio-chemical water quality, a water analysis is presented. Water sample was taken from the lake at the pumping station, 20 m below the lake level, in the spring of 1992.

It is clear that the analyzed water belongs to the calcium-bicarbonate type with a slightly higher magnesium content. All the components are within limits requested for the drinking water. We wish to emphasize especially the high quality of that water when its bacteriological composition is concerned. The chlorides content, 59 mg/l, is higher than in spring waters of the mainland but it is in accord with the salinity of water in other Adriatic islands and even with the waters from insular cisterns. In several figures, physio-chemical changes in the lake bottom water will be shown. These changes illustrate the potential groundwater entrance into the lake. The samples were collected in the spring of 1992.

The minimal temperature, 8.9 °C, was recorded in a doline-type depression, at the lake depth of 70 m, in the southern part of the lake (Fig. 2.5.2.2 and 2.5.2.3). Water temperature is 9.1 °C at the flattened lake bottom. The boundary of stable lake water temperature is at the lake depth of 20 m with the water temperature of about 12 °C. From that depth, lake water temperature changes to higher or lower values. So, the lake water body below the depth of 20 m has a stable temperature. It is to mention that the temperature from the bottom is typical for deep groundwater in the Dinaric karst. The value of pH (Fig. 2.5.2.4 and 2.5.2.5) also changes within the lake water body. Lower values are at the bottom and in the doline-depression and become higher toward the lake surface. The lower values are similar to those that may be usually found in karst groundwater while the higher values resemble to those of karst surface streams.

The chlorides content (Fig. 2.5.2.6 and 2.5.2.7) ranges between 61 and 69 mg/l. The highest content, 69 mg/l, is in the doline-depression and becomes lower in the central part of that depression. It is still lower toward the lake surface. All that reflects a partial downward concentrating or the effect that may be caused by freshwater input from precipitation. It is necessary to mention that the chloride content is fully homogeneous throughout the lake and that we shall be able to speak, probably, more accurately about the reasons of the mentioned small differences in chlorides content after completing the present phase of exploration.

The oxygen content (Fig. 2.5.2.8 and 2.5.2.9) is high and demonstrates an oxidation medium within the whole lake. A somewhat higher content near the lake surface reflects the dynamics of that surface zone. The presence of free oxygen in the doline-like depression could be associated with the transport of oxygen from the deep karst underground but also with the relatively low water temperature at the lake bottom.

The water alkalinity (Fig. 2.5.2.9 and 2.5.2.10) is highest in the lake depression. These values are very close to those recorded in karst groundwater while the values obtained from the lake surface correspond to those of surface karst streams.

The good quality of lake water has since many years been maintained thanks to special protection measures set at the entire lake area. Any activity, except the water supply, has been forbidden at the lake. The coast slopes are partly used for sheep breeding but without a concentration within one site, thus, without harmful effects. Even a small village has been practically abandoned. The main insular road makes a potential environmental risk since it passes over the local drainage area. The traffic is relatively small and for the time being does not affect the lake.

The global climatic changes till the year 2050 will not have a major effect on the Lake of Vrana. The increase of mean annual temperature of up to 1.1 °C will negligibly change ecological conditions of the lake. A slightly higher warming of the superficial lake zone, above the depth of 20 m can be a possible consequence of those changes. Below that depth, there is a zone of thermal stability. Eventual decline of the lake level will push that zone slightly downward but without harmful effects on water supply pumping. Namely, the pump suction strainer are submerged into the zone of thermal stability. Favourable water temperature conditions will be maintained also by the inflow of deep groundwater through the doline-like depression. The sea level rise of up to 0.75 m will not have also a major effect on the chlorides content in the lake water.

The climatic changes till the year 2100 expressed in the rise of mean annual temperature ranging between 3.0 and 3.3 °C can have a major influence on the lake, especially if the proposed measures for groundwater resources conservation will not be materialized (artificial groundwater recharge in the Kvarner mainland from surface storage). Especially negative effects may take place in the lake water salinity due to the sea level rise of up to 1.94 m above the present level. That is to say, the lake water chlorides content may be considerably increased. All that may harmfully affect the lake biocoenosis and, indirectly, the drinking quality of lake water.

It is impossible to adapt to the consequences of climatic changes because the increase of lake water salinity will result in becoming that water entirely useless for public water supply and in an entire change of herbal and animal lives. However, these harmful consequences can be avoided if the proposed and in chapter 2.3 described protection constructions and activities will be realized.

A permanent hydrochemical exploration of the lake may warn on time if any change of lake water chemistry appears and, by that, to contribute in the selection of the proposed protection activities and the dynamics of their completion.

Past trends and present situation

The fresh water ecosystem is closely connected with the hydrosphere of Lake Vrana described in section 2.3. The ecosystem is under special protection covering the whole lake area, which forbids any activity connected with the use of the lake as source of water supply for archipelago. It consists of elements typical for fresh water lakes with stable temperature and hydrochemistry.

The physical and chemical properties of water in Vransko jezero (Lake of Vrana) are stable: the temperature is well-balanced, varying between 8 °C and 11.5 °C in deeper strata, while at the surface was recorded a June temperature of 22 °C. The concentration of dissolved O_2 is relatively uniform all the way from the surface to the bottom, surpassing the figure of 100% for the total water column. Quantities of nutrient salts are low, pointing to a low production of organic matter and oligotrophic character of Vransko jezero. Bacteriological investigations established that from the hygienic point of view the Vransko jezero water possesses very good qualities, as it is not burdened with faecal bacteria to some more significant concentrations. Planktonological investigations indicate that both the phytoplankton and the zooplankton components are relatively poorly developed and that the water of Vransko jezero therefore ranks into the 1st quality class.

In the Vransko jezero waters live the following species of fish:

the *Cyprinidae* family is represented by four species - Rudd (*Scardinius erythrophtalmus ssp. hesperidicus* and *ssp. scardafa*), Tench (*Tinca tinca*) and Chub (*Leuciscus cephalus albus*). The *Esociidae* family - Pike (*Esox lucius*), as well as the *Anguillidae* family, represented by the species Eel (*Anguilla anguilla*). The density of fish colonies has not been scientiffically determined.

Expected effects, and most vulnerable systems and activities

Considering the fact that the lacustryne system of Vransko jezero forms a very stable system, it is not to be expected that the foreseen climatic changes be the cause of changes within the lacustrine ecosystem, either in regard of altering of the existing biocenoses or the density of existing populations.

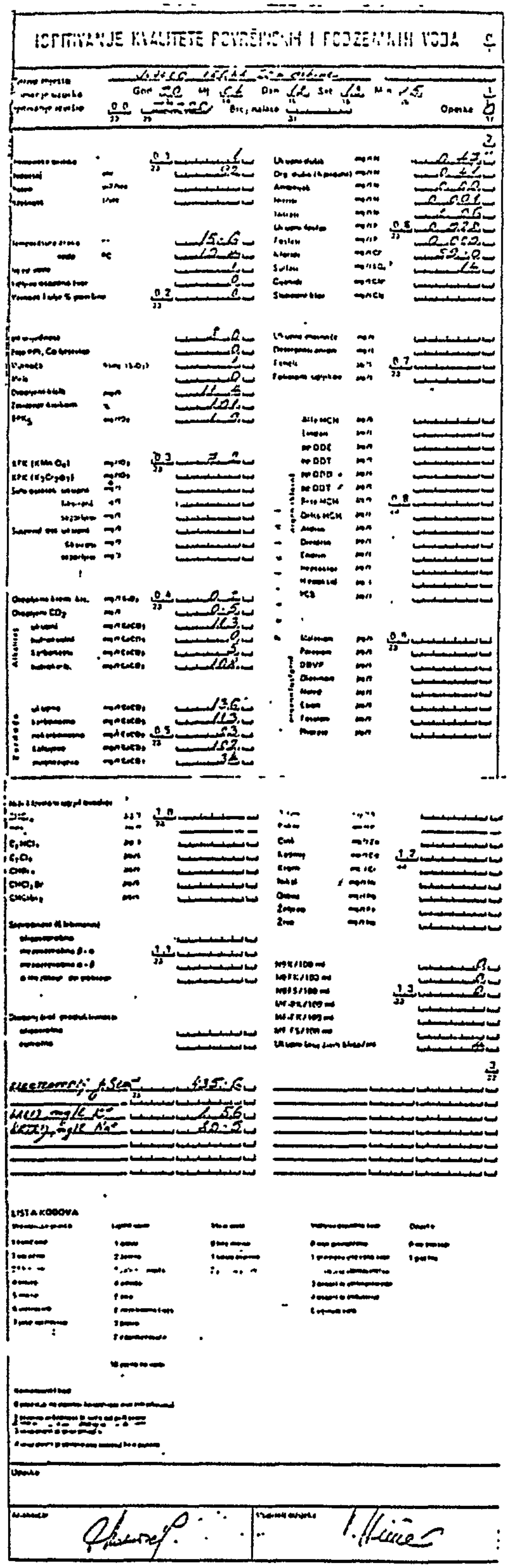


Figure 2.5.2.1 Water quality of the Vrana Lake

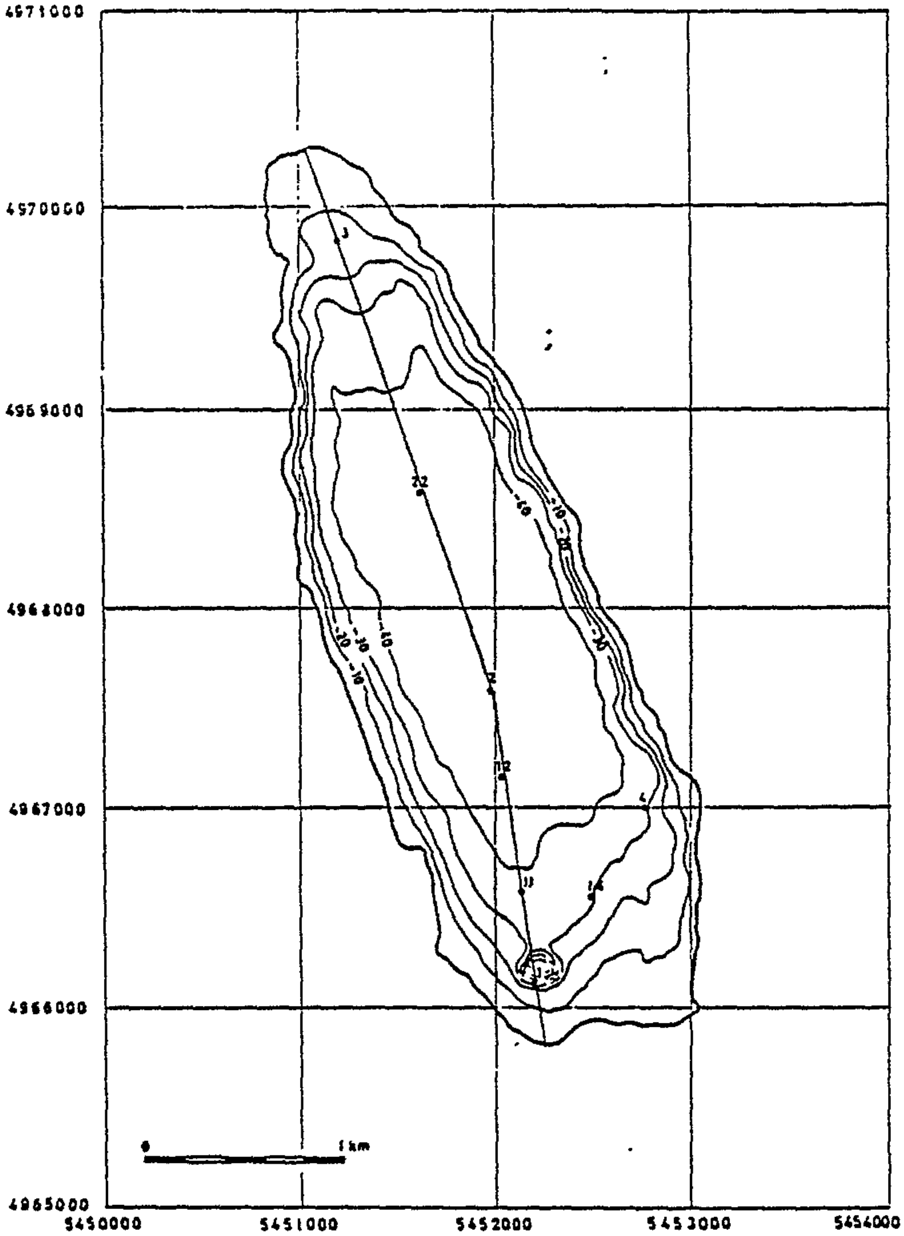
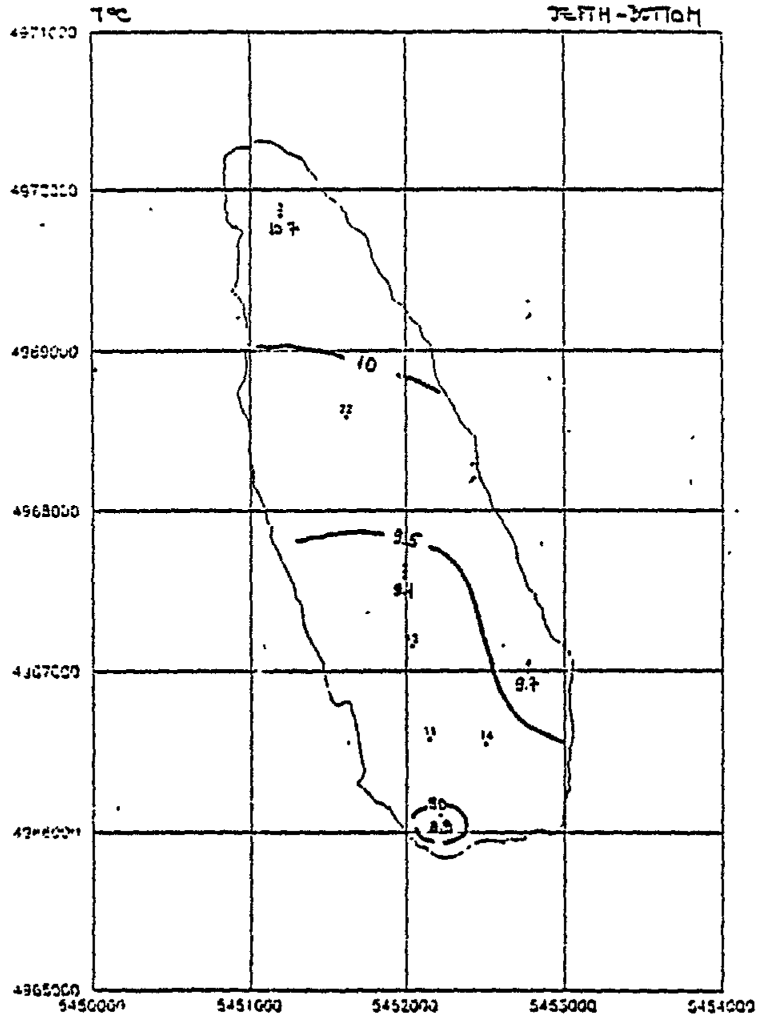


Figure 2.5.2.2 Water quality control positions



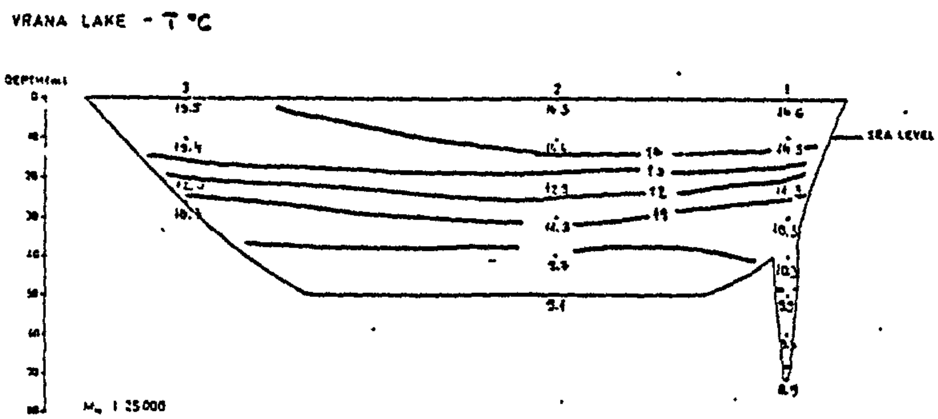


Figure 2.5.2.3 Temperature of the lake water

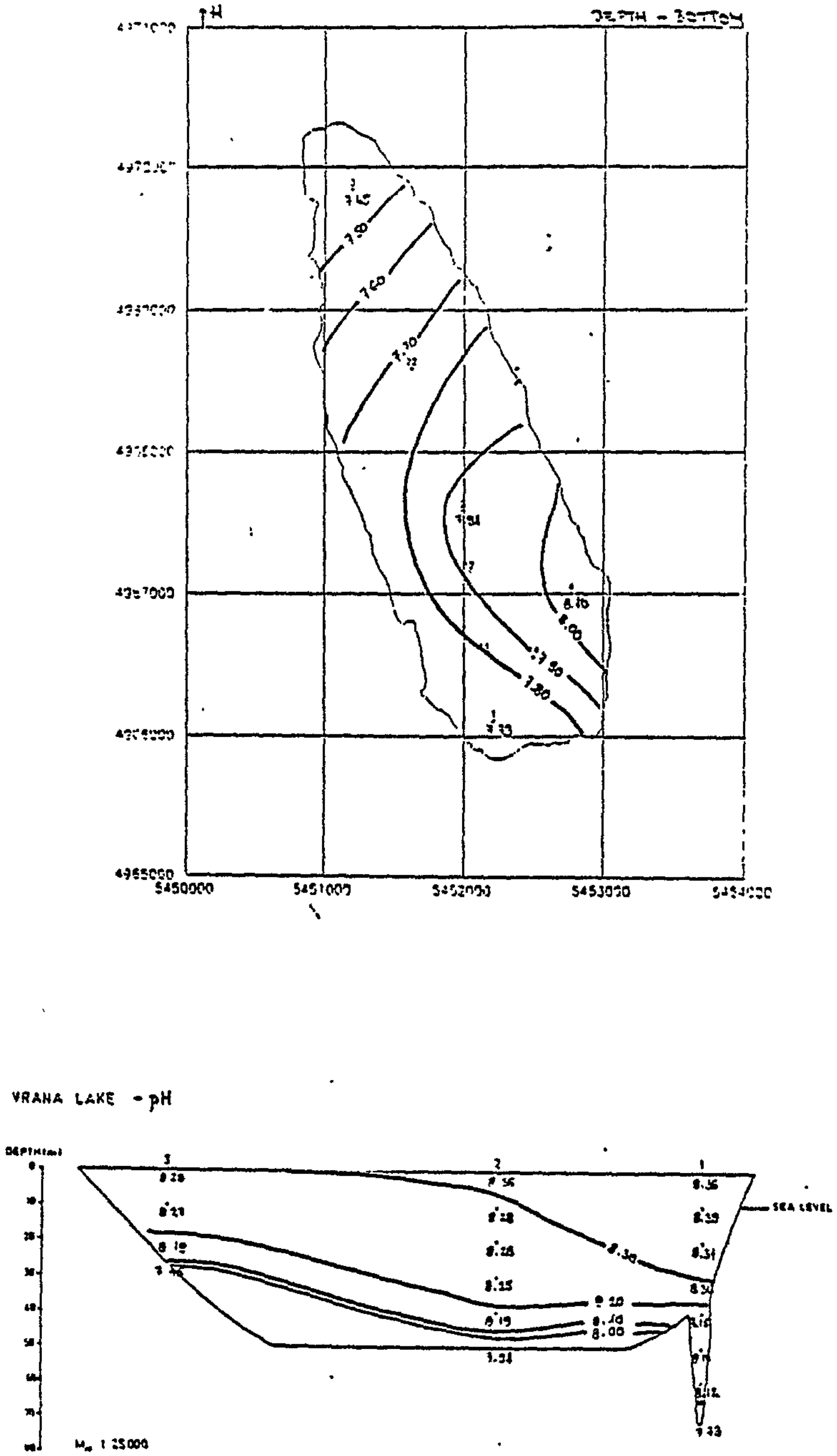


Figure 2.5.2.4 pH of the lake water

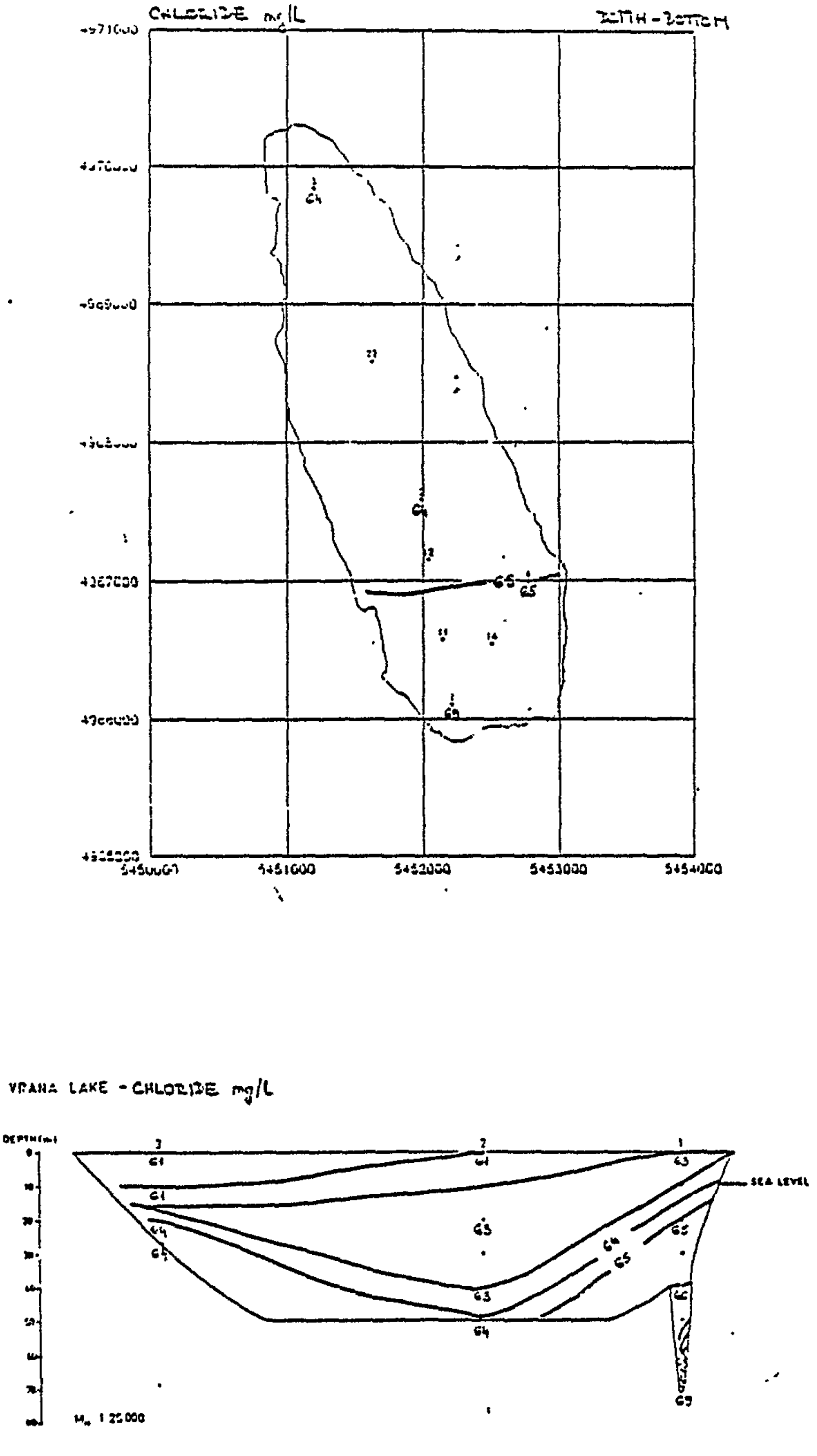
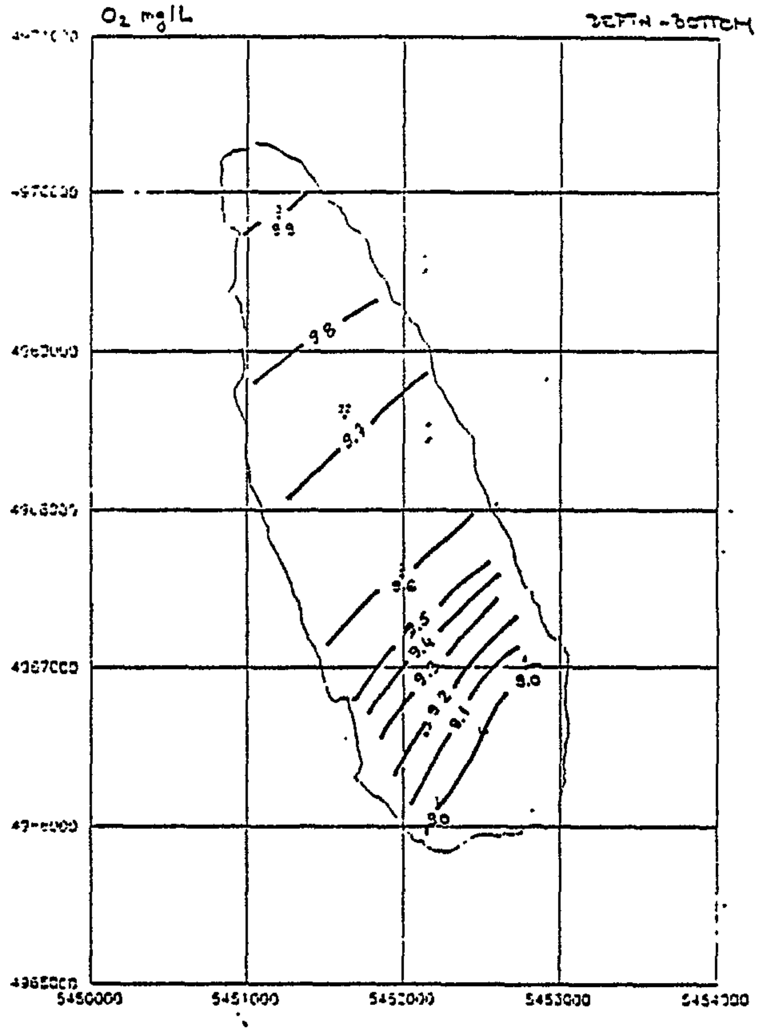


Figure 2.5.2.5 Chloride content of the lake water



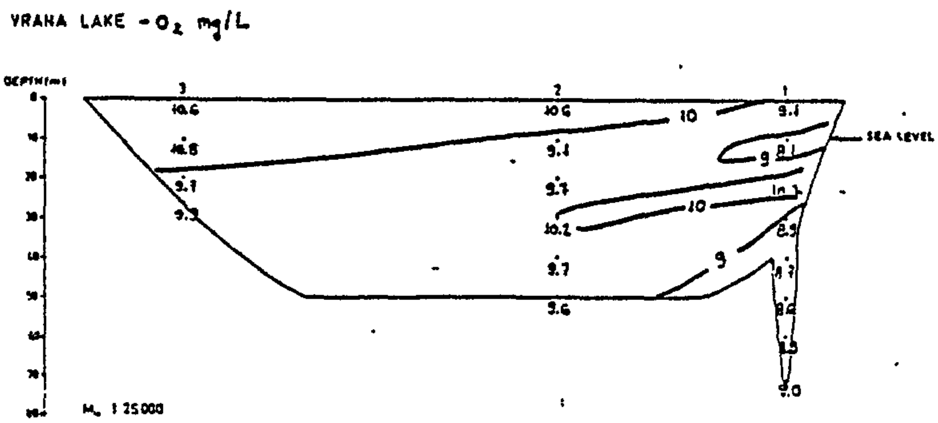
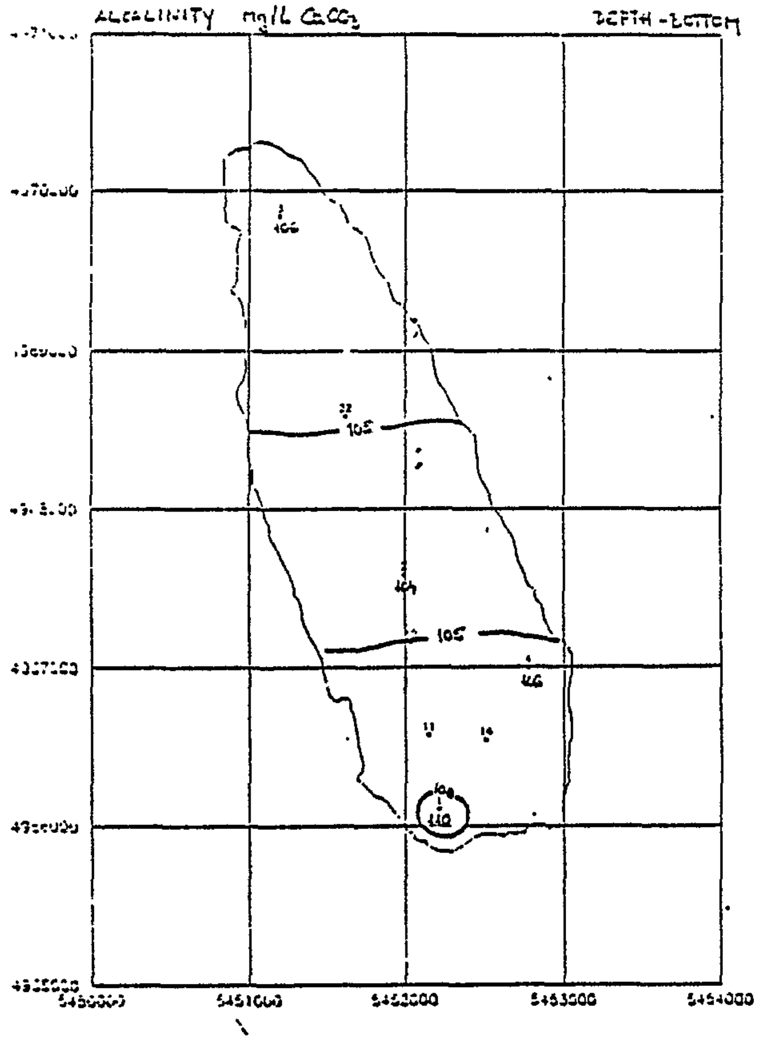


Figure 2.5.2.6 Oxygen content of the lake water



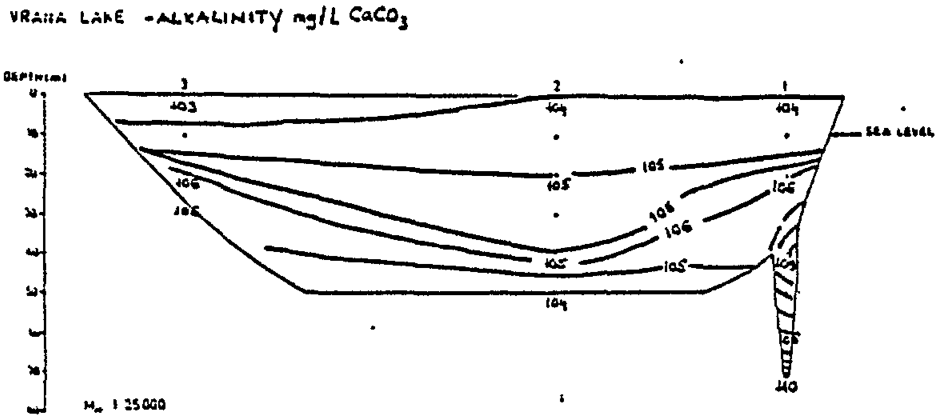


Figure 2.5.2.7 Alkalinity of the lake water

2.5.3 Marine Ecosystems

The marine environment surrounding the Cres-Losinj archipelago is under heavy influence of meteorological, oceanographic and hydrological conditions prevailing in a wide region encompassing the drainage basin of the northern and central Adriatic. The geochemical and biological processes in the Cres-Lošinj area are particularly affected by water exchange with both the central and northern Adriatic, in addition to local freshwater inputs and physical processes. Therefore the local climatic changes predicted for the archipelago, based on existing historical data series for air temperature and rainfall and a mathematical model (see section ..... of this report), are expected to exert only a relatively small effect on the marine environment surrounding the archipelago. The main effects which may be expected will be due to:

- changes in the rainfall in the watersheds of the Kvarner region which may significantly increase the freshwater input into the waters to the north of the Cres island;

- changes in the oceanographic, chemical and biological properties of the central Adriatic, which represents the major source of water masses in the Bay of Kvarner in which the archipelago is situated;

- changes in the exchange of waters between the northern Adriatic and the Bay of Kvarner, whose waters differ significantly in chemical and biological characteristics; these changes will be mainly influenced by the changing pattern in freshwater discharges from the Po river and the minor northern Adriatic watersheds although they are most likely to be restricted to surface layers during summer.

THE PRESENT STATE

Tides and other sea-level oscillations

The maximum sea-level variations, due to astronomic tides, is around 80 cm below and above the mean level (Stravisi, 1991). These changes are more marked in the northern Adriatic than in the central and southern areas. For example, the mean annual tidal amplitude ranges from 11.5 cm near Dubrovnik in the southern Adriatic, to 16.6 cm near Bakar (north of the Cres - Losinj archipelago in the Bay of Rijeka), and 24.5 cm near Rovinj in the northern Adriatic (Buljan and Zore-Armanda, 1976). Rotatory motions of the tidal wave prevail in the Adriatic (Purga et al., 1979), with an amphidromic point located in the middle of a line between Ancona and Zadar (Buljan and Zore-Armanda, 1976).

Sea-level changes are also caused by various meteorological perturbations, particularly by winds and air pressure fluctuations (meteorological tides). These changes are hardly predictable and their frequency can vary from hours to several days. An air pressure change of 1 hPa induces a 1 cm sea-level change. Winds of 10 m s^{-1}, most frequently occurring as "bora" ("bura") and "scirocco" ("jugo") winds, generate sea-level changes of up to 10 cm. Southern winds also generate seiches, whose basic periodicity in the open sea is either 22 or 11-12 h, with an amplitude as great as 50 cm. In addition there is an entire spectrum of other free oscillations, particularly in the bays and channels along the eastern Adriatic coast, in the Velebit Channel a 2.2 h period oscillation was determined, for example (Buljan and Zore Armanda, 1976; Mosetti, 1983; Leder et al., 1987).

The combined influence of low air pressure and strong southerly winds can cause a relative sea-level rise of 130 cm in the northern Adriatic, which can reach as much as 200 cm when meteorological and astronomical forcing are superimposed (Stravisi, 1991). High air pressure, combined with the "bora" wind, can reduce relative sea level by as much as 60 cm.

Waves

Long-term wave observations from ships (1957-1971) were analyzed for the quadrant delimited by 44 °N and 45 °N, and 14 °E and 15 °E, which encompasses the greater part of the Cres-Lošinj archipelago (Anon., 1979). Calm sea is most frequent in spring and summer (monthly averages ranging from 35-46 % of observations), particularly in June and July, in comparison with the fall and winter (20-31%). In the winter months mean and maximum wave heights (0.6-1.25 m and 1.5-3.5 m, respectively) are higher than during the spring and summer (0.4-0.9 m and 1.0-1.25 m, respectively). The highest waves develop in January from the north and south directions, in October from the south, and in December from the north-east. Throughout the year, but particularly in winter, waves from the NE (due to "bora" wind) are the most frequent, followed by those from the SE while, in contrast, W and SW directions occur only rarely.

Real maximal wave height data are not available from ship based observations and unfortunately, direct wave measurements are scarce in this area. One of the few measurements has shown that "bora" winds of 15 m s^{-1} generated waves up to 3 m height in the Kvarnerić Region near the Cres coast, but much higher waves (up to 6 m) in the open sea off the Kvarner region (Smirčić et al., 1987). Exceptional waves of up to 11 m height from a southerly direction generated by "scirocco" winds have been measured in the open sea (A. Smirčić, personal communication).

Water exchange and dynamics

Gradient currents represent the principal water exchange mechanism in the open Adriatic (see Buljan and Zore-Armanda, 1976 and Mosetti, 1983 for review). Density gradients are mainly due to significant seawater dilution with freshwater in the northern Adriatic, particularly in spring and summer, and to a more marked winter water cooling in the same region, compared with the rest of the Adriatic. This results in a basic cyclonic current system in the surface layer: a NW current in the eastern Adriatic, an arm of which flows throughout the Cres-Lošinj area, reverses direction in the northern Adriatic and after mixing with freshwater, flows SE off the western Adriatic shore (Fig. 1a). In winter, the eastern arm is more marked and the input of Mediterranean water dominates the influence of the dilute waters of the northern Adriatic. In summer the SE outflowing current is relatively more important. Compensation currents occur in the intermediate and bottom layers.

Atmospheric pressure differences between the North Atlantic and eastern Mediterranean significantly influence the NW current intensity and water exchange between the Adriatic and Ionian seas. Periodically, approximately each 10 years (Buljan, 1969) these pressure gradients increase significantly, followed by massive cold air mass intrusions from the north. As a consequence, an "ingression" (up to 30 times the normal inflow) of more saline (>38.7) and warmer, intermediate water of Levantine origin occurs (Zore-Armanda, 1969; Zore-Armanda and Pucher-Petković, 1976). During "ingression" periods, dense waters are generally formed in the northern Adriatic, due to increased salinity and more intense winter cooling. These waters are one of the source of deep eastern Mediterranean water.

In spring and autumn transverse currents prevail, particularly in the regions between Stončica Island and the Gargano, and Ancona and Zadar, reducing water exchange rates between the principal Adriatic basins (Buljan and Zore-Armanda, 1976). In the northern Adriatic region during the spring, eddy circulations are established as a consequence of increased freshwater discharge (Franco et al., 1982; Zore-Armanda and Vučak, 1985; Cerovečki et al., 1991). One cyclonic eddy is formed in the northernmost part of the region, another in the south (Fig. 1b), which can contribute in combination with northern Adriatic water, to the formation of the surface layer in the western parts of the Cres-Lošinj region (Bay of Kvarner, Vela Vrata and Bay of Rijeka;

Degobbis, 1983). Due to this circulation pattern, surface waters with reduced salinity are redistributed during the summer over most of the region (Orlić, 1989; Gilmartin et al., 1990). Similar eddies can be formed temporarily during the winter under the influence of strong "bora" winds (Orlić et al., 1986; Kuzmić and Orlić, 1987).

In winter, water flows in the Bay of Rijeka from the Kvarnerić region out into the Bay of Kvarner (Degobbis et al., 1978; Orlić and Kuzmić, 1980; Legović, 1982). This cyclonic circulation can be significantly accelerated by "bora" winds, and velocities up to 1 m s^{-1} can be measured. At the end of spring water exchange between the three regions is at a minimum. During summer, the bottom layer retains the winter pattern; surface water flow is reversed into an anticyclonic pattern. Near the coasts, the main factors generating currents are tides and winds, particularly the "bora" wind, hence local circulation is highly variable and unpredictable.

During the summer, current velocities in Osor Bay are generally very low (<0.2 m s^{-1}), variable, and tide dependent (Degobbis et al., 1989). In the Osor Channel the velocities can reach 1.5 m s^{-1}, but the direction is frequently reversed (5-60 min) and no significant net water exchange occurs between the Osor Bay and Lošinj Channel.

<u>Surface salinity and freshwater dispersion in the sea</u>

The volume of the Adriatic basin ($3.5 \cdot 10^4$ km^3) is only 1/106 of the total volume of the Mediterranean ($3.7 \cdot 10^6$ km^3), but it receives one third of the total freshwater input to the Mediterranean basin. In the northern Adriatic, whose volume is 1 % of the Adriatic volume, the freshwater inflow is around 60 % of the Adriatic total and 60 % of this comes from the Po River. It has been estimated that the Adriatic receives an average of 142 km^3 y^{-1} of freshwater of which, 45 km^3 y^{-1} comes from the Istrian, Kvarner and central Dalmatian watersheds (mainly karstic underground streams; Cavazzoni Galaverni, 1972). An estimated 2.2 km^3 y^{-1} enters Rijeka Bay. In the northern part of this region freshwater is diffusively discharged from numerous karstic springs and underwater wells, together with minor amounts from the Rječina River, urban and industrial wastewater outfalls (Degobbis, 1981).

Freshwater discharges generate marked salinity and temperature gradients between the western and eastern northern Adriatic coasts (Štirn, 1969; Franco, 1970, 1972a; Bičanić, 1989), as well as between the northern and southern parts of the Cres-Lošinj area (Fig. 2; Škrivanić and Barić, 1979a; Degobbis, 1981). Freshwater influence in this area is highly variable, and most marked in the northern coastal area of Rijeka Bay, where surface salinity varies between 23.0 and 37.8. In the rest of the bay, including Srednja and Vela Vrata, variations are less marked, but still significant (32.6-38.1). In contrast, in the Kvarner and Kvarnerić areas, salinity generally decreases down to about 36.5 (Degobbis, 1983). During periods of extreme increase in freshwater inputs, even lower salinity values have been measured (about 35 in July 1977 in Osor Bay; Degobbis et al., 1989). In the subsurface layers, and particularly near the bottom, salinity variations are significantly lower (37.5-38.5).

<u>Water column stratification</u>

Stratification in the northern Adriatic generally starts to develop in April, when the sea surface warming is significant. Maximum stability is reached in August followed by gradual destrafication to October, under the influence of convective and wind mixing (Degobbis, 1988). In the years when the influence of freshwater is greater, this process can be extended over a longer time period (from February to December).

The surface water temperature of Rijeka Bay is at a minimum in February/March (on average 10.5 °C) increasing in April (Fig. 3). In July, air temperature is at a maximum in the Adriatic, but over most of Rijeka Bay, including Vela and Srednja Vrata, the maximum occurs in August (22.4 °C). The maximum and mean surface water temperatures in Rijeka Bay are 2.5 °C and 1.5 °C lower than those in the open waters of the northern and central Adriatic. The minimum value is 1.5 °C higher than in the northern Adriatic and 3.0 °C lower than in the central Adriatic waters.

Warming of deeper layers, separated from the surface by pycnoclines, is significantly delayed and starts only in July/August. The temperature maximum in the bottom layer occurs in October and is on average 15 °C.

Due to the combined influence of heat exchange, freshwater influence, wind action and other factors, the water column structure in the Cres-Lošinj area is variable and characterized by several layers and pycnoclines (Degobbis, 1981). During spring and summer, temperature changes are the major influences on water column structure, but over most of Rijeka Bay, Vela and Srednja Vrata salinity is also significant and accounts for between 15 and 25 % of the vertical differences in density (1.0-4.5 g dm^{-3}). In winter and autumn, stratification is occasionally established but is limited to the surface layers, when freshwater influence is more marked (density difference up to 1.5 g dm^{-3}).

Water transparency

The open waters of the central and southern Adriatic are highly transparent (Secchi disk readings are in the range of 14-56 m, on average 30 m; Buljan and Zore-Armanda, 1976). In the northern Adriatic transparency is lower and highly variable (0.5-31 m; Franco, 1972b; Smodlaka and Degobbis, 1987). The depth of 1 % of incident light intensity in the central Adriatic is twice as high as in the northern parts (Škrivanić et al., 1969; Kansky et al., 1970; Franco, 1983). A blue color is typical for open waters in the central and southern Adriatic (Tešić and Vučak, 1969). Waters of lower transparency are generally green, and less frequently brown, depending on the species of phytoplankton present.

In the Cres-Lošinj area, transparency varies from 7-32 m, and water color is generally blue-green (Precali and Smodlaka, 1983; Škrivanić and Barić, 1979a). In the southern parts of this area higher transparency values prevail.

Dissolved oxygen

Oxygen concentration in the waters of the central and southern Adriatic vary around the solubility values, except in the bottom layer of Jabuka Pit (70 % saturation, exceptionally down to 50 %; Anon., 1982; Zore-Armanda et al., 1991). In contrast, oxygen saturation in the bottom waters of the northern Adriatic may be as low as zero (anoxia) (Degobbis et al., 1991a) and as high as 270 % in the surface layer (Smodlaka and Degobbis, 1987). Significant supersaturation generally occurs during late winter and spring, and in the mid-autumn, when phytoplankton activity is high (Gilmartin et al., 1990). The most marked oxygen depletion of bottom water below the pycnocline is observed in mid-autumn when oxygen consumption during decomposition of organic matter exceeds photosynthetic production. During late autumn and winter biological activity is minimal and effective vertical mixing leads to oxygen redistribution throughout the entire water column (90-100 %).

Over most of the Cres-Lošinj area oxygen saturation varies between 80 and 130 % (on average 105 % in summer, 95 % in winter; (Škrivanić and Barić, 1979a; Degobbis, 1982; Degobbis et al., 1989). Lower values down to 55 % can occur near the bottom in the central part of Rijeka Bay.

Nutrient concentrations

Nutrient concentrations are significantly lower in most of the Adriatic than in the Atlantic, or, even the surface waters of the western Mediterranean (Buljan et al., 1975; Cescon and Scarazzato, 1979). Orthophosphate, concentrations are generally below 0.05 μmol dm^{-3}; total inorganic nitrogen ranges from 0.0 to 2 μmol dm^{-3}; and, orthosilicate concentrations from 0.2 to 2.5 μmol dm^{-3}.

Marked changes in nutrient concentration were measured in the northern Adriatic, particularly along salinity gradients, and in the deoxygenated bottom layers. Open water orthophosphate concentrations vary between 0.00 and 1.1 μmol dm^{-3} (average 0.08 μmol dm^{-3}); total inorganic nitrogen from 0.0 to 78 μmol dm^{-3} (average 2.2 μmol dm^{-3}); and orthosilicate from 0.0 to 59 μmol dm^{-3} (average 4.1 μmol dm^{-3}; Gilmartin et al., 1990). Interestingly, in the western coastal Po River "plumes" values for inorganic nitrogen and orthosilicate are similar to those of the western open waters, but orthophosphate concentrations can be much higher (up to 8 μmol dm^{-3}; Franco, 1984).

Nutrient concentrations are higher in the fall and winter compared to spring and summer, when biological productivity is highest (Gilmartin et al., 1990). Nitrate and orthosilicate concentrations change more markedly compared to other nutrient species, since they are the principal chemical forms in freshwater discharge, as well as the final regeneration products from organic decomposition. Significant nitrite accumulation occurs in late summer, when nitrification processes exceed the rate of ammonium uptake by phytoplankton. Orthophosphate is generally very low, but can significantly accumulate in near anoxic bottom waters through desorption processes involving some metal (mainly iron) oxides and hydroxides (Degobbis, 1990). This is one of the reasons for the significant differences between northern Adriatic and the oceanic waters, involving stoichiometric regeneration ratios among nutrients and apparent oxygen utilization (AOU). Other possible causes may include sediment denitrification and lower organic matter phosphorus content than in the ocean.

For most of the Cres-Lošinj area total inorganic nitrogen and orthosilicate are on average twice as high as in the open central Adriatic waters, due to inputs from freshwater (Degobbis, 1983). In contrast, orthophosphate concentrations are slightly higher than in the open sea, with occasional maximal values up to 0.15 μmol dm^{-3} in some coastal areas (e.g., near Rabac, Osor Bay; Degobbis et al., 1987, 1989). In the open Kvarner and Kvarnerić areas values are similar to those in the central Adriatic (Škrivanić and Barić, 1979b; Degobbis, 1983).

Primary production and organic matter

Annual primary production was estimated to range from 55 gC m^{-2} y^{-1} in the open sea to 150 Gc m^{-2} y^{-1} in the river "plumes", lagoons and polluted harbors (Sournia, 1973; Homen, 1979; Pucher-Petković et al., 1988). In the western part of the open northern Adriatic (100-120 gC m^{-2} y^{-1}) primary production is significantly higher than in the eastern part and in Istrian coastal waters (55-80 gC m^{-2} a^{-1}; Gilmartin and Revelante, 1983). The potential rate of primary production in the northern Adriatic can vary within three orders of magnitude (0.1-163 mgC m^{-3} h^{-1}; Gilmartin and Revelante, 1983; Smodlaka, 1986).

In the open northern Adriatic chlorophyll a concentrations vary from 0.0 to 100 μg dm^{-3}, with maxima up to 250 μg dm^{-3} in the Po River "plume" (Franco, 1973; Socal et al., 1982; Gilmartin and Revelante, 1983; Smodlaka, 1986). In the eastern parts, values as high as 13 μg dm^{-3} were measured occasionally (Degobbis et al., 1979). In the open central and southern Adriatic maximal values are at least an order of magnitude lower (i.e., about 1 μg dm^{-3}; Anon., 1982; Faganeli et al., 1989).

Over most of Rijeka Bay, including the Vela and Srednja Vrata regions, as well as in the Osor Bay during summer, chlorophyll a concentrations were lower than 1.5 μg dm^{-3}, and potential primary production rates were lower than 22 μGc dm^{-3} h^{-1}, with maximum values in April (Smodlaka, 1983; Degobbis et al., 1989).

Nanophytoplankton (<20 μm) production rates and chlorophyll a concentrations are generally an order of magnitude higher than for the microplankton fractions. Exceptions are blooms in the most eutrophic northern Adriatic areas, when the two fractions contribute approximately equally to total production (Homen, 1979; Gilmartin and Revelante, 1983; Smodlaka, 1986). In contrast, nanoplankton always dominate blooms in Rijeka Bay (Smodlaka, 1985).

Primary production is the main source of organic matter in the northern Adriatic, as shown from biomarker composition (fatty acids and hydrocarbons; Najdek, 1991).

Phytoplankton community

The composition of the phytoplankton community of the Adriatic is typical for oligotrophic seas, with marked dominance of the nanoplankton fraction. The nanoplankton species composition is not yet known (Pucher-Petković, 1979; Pucher-Petković and Homen, 1979; Revelante and Gilmartin, 1983a). Total nanophytoplankton densities vary from 0.5-80·10^6 cells dm^{-3} in the open northern Adriatic waters, to 0.1-0.4·10^6 cells dm^{-3} in the central and southern Adriatic (Revelante and Gilmartin 1983; Viličić, 1991). In Rijeka Bay values are intermediate: 10^3-10^6 cells dm^{-3} (Smodlaka, 1985).

Northern Adriatic nanoplankton blooms are more intense in spring and summer (Gilmartin and Revelante, 1980; Smodlaka, 1985). During late winter, late spring and in autumn microphytoplankton species blooms occur, particularly in the western regions, where the freshwater influence is more marked. In these regions (25 km off the Po Delta) densities up to 19000·10^3 cells dm^{-3} were measured (Degobbis, 1989; Filipić, 1990). In the central and southern Adriatic microphytoplankton densities are at least two orders of magnitude lower (5-100·10^3 cells dm^{-3}; Pucher-Petković, 1963; Revelante and Gilmartin, 1977, 1983; Fanuko 1983/1984; Viličić, 1991).

Microphytoplankton species composition and distributions are well known. In eutrophic areas, diatoms (*Skeletonema costatum*, some *Nitzschia, Chaetoceros, Leptocylindrus*, and other species; Pucher-Petković, 1975; Voltolina, 1971; Revelante and Gilmartin, 1976, 1983) dominate the microplankton community. In the central and southern Adriatic coccolitoforids are important (*Syracosphaera pulchra, Acanthoica aculeata, Pentosphaera huxleyi*), as well as, but to a lesser extent, warm water dinoflagellates (Pucher-Petković, 1971; Revelante and Gilmartin, 1977; Fanuko 1983/1984).

In the central and southern Adriatic open waters the most frequent diatoms are *Thalassiothrix fraunfeldii, Rhisosolenia alata f. gracillima, Chaetoceros compressus, Thalassionema nitzschioides* (Pucher-Petković, 1966; Fanuko, 1983/1984).

Dinoflagellate blooms are restricted to estuarine and polluted areas (most often due to *Prorocentrum micans* and *Gonyaulax polyedra*). No toxic species were identified, with the exception of potentially toxic *Prorocentrum minimum* in the Gulf of Šibenik (Marasović, 1986) and occasionally in the "plumes" of river Po "plumes". The occurrence of *Dynophysis forti* is rare, and mostly limited to open waters.

Zooplankton community

The zooplankton biomass of the northern Adriatic is higher and more variable seasonally (mean ranges 1.2-177 μg dm^{-3}) than in the central and southern Adriatic open waters, including the Cres-Lošinj area (0.5-30 μg dm^{-3}). In the open sea the zooplankton biomass is at a maximum in spring, but in the Cres-Lošinj area in winter (Benović et al., 1984). Generally, copepods represent the most important Adriatic mesozooplankton fraction, particularly in winter (Hure et al., 1980; Regner et al., 1985), when the highest caloric contents were measured (Benović, 1979). In the southern Adriatic 150 copepod species were identified, but this number decreases significantly towards the north. In the northern Adriatic half this number of species occur, but only a few contribute to more than 50% of the total density. Such a south-north trend is valid also for other species, except in the case of cladocerans.

Four zooplankton community types have been defined for the Adriatic, each dominated by characteristic species (Hure et al., 1980; Fonda-Umani et al., 1989a; Ghirardelli et al., 1989; Regner, 1985):

(a) estuarine neritic: in the estuaries, including most of the northern Adriatic and the western coastal belt up to Gargano, in which the Po River influence is significant; the most common copepod species are *Paracalanus elongatum* and *Temora longicornis*;

(b) coastal neritic: in the northern Adriatic, limited by community (a) and the 100 m isobate, as well as in the southwestern coastal belt and in the eastern Adriatic channels and gulfs; common copepod species include *Acartia clausi, Paracalanus parvus, Centropages typicus* and *Temora stylifera*;

(c) open sea (Ionic) type: in the open southern Adriatic waters, with about 15 important copepod species; and,

(d) mixed (b) and (c) type with different seasonal ratios in the central Adriatic.

Cladocera, in comparison with other zooplankton species, are more diverse in the northern Adriatic, where their density is at a maximum during summer exceeding that of copepods (Franco and Comaschi-Scaramuzza, 1976; Fonda-Umani et al., 1989a). In this region all 6 species known from the Mediterranean are found, with *Penilia avirostris* being the dominant species. In summer four species were found in the central Adriatic, but *Cladocera* are very rare in the other seasons.

In the Cres-Lošinj area the copepods are dominated by typical coastal species (Hure et al., 1979; Benović et al., 1981).

Eggs and larvae of numerous benthic and nektonic organisms, including fishes, also occur in the plankton (e.g., Piccinetti et al., 1979a,b; Regner et al., 1987). In addition about 30 hydromedusae species (Schmidt and Benović, 1979), 2-3 *Thaliacea* species (Katavić, 1979), and about 10 *Appendicularia* species have been identified. Of the latter, three species account for at least 95% of total *Appendicularia* density (Skaramuca, 1979).

Northern Adriatic ciliate protozoans account for 90 % of the total microzooplankton density in winter, and up to 98 % in summer (Revelante and Gilmartin, 1983b). In summer, densities (on average 5220 individuals dm^{-3}) are about 10 times higher than during winter, but the biomass is only double, due to a shift towards smaller fractions. About 70 % of ciliates and 40 % of tintinnids are smaller than 30 μm. In Rijeka Bay microzooplankton biomass is also at a maximum in summer (Kršinić, 1981).

Bacterioplankton (heterotrophic bacteria)

In the open northern Adriatic, total heterotrophic bacteria density (as determined by epifluorescent microscopes) varies between 1.1 and $80 \cdot 10^8$ cells dm^{-3} (Fuks and Devescovi, 1990), and in the central Adriatic, near Vis Island, between 2.5 and $30 \cdot 10^8$ cells dm^{-3}, representing 5-45 % of total plankton biomass measured as organic carbon (Krstulović and Šobot, 1982).

Benthic communities

The Cres-Lošinj archipelago is composed of cretaceous limestone with the exception of Susak Island which is formed of pleistocene fine sands. Thus the coastal area is characterized by limestone rocks and cliffs displaying typical karstic geomorphological features. At greater depths in the lower infralittoral and in the circalittoral zones, the sea bottom consists mostly of fine well sorted sands and gravels locally rich in detritic particles. Silty sediments, are restricted to open areas of Kvarner Bay and the Lošinj channel. At some sites coastal slopes are very steep or nearly vertical down to the areas of sandy and silty plains.

The marine flora and fauna around the archipelago mostly consists of atlantic-mediterranean and endemic mediterranean taxa which are assembled in communities depending on the various oceanic-climatic and substrate factors. The following benthic ecosystems and communities are characteristic of the area (Zavodnik, in press):

- supralittoral community of rocky shores widely distributed and most developed at exposed sites;

- midlittoral rocky shore community characterized by special facies common to other parts of the Adriatic Sea and the Mediterranean; the extent of gravel and sandy beaches is limited and their biota remain undescribed;

- biota of the upper sublittoral zone, on rocky substrates dominated by algae, which at some sites are suppressed by sea urchins; sandy sediments in this zone support local seagrass beds of *Cymodocea* and *Zostera*;

- eelgrass *Posidonia oceanica* communities on the coarse sand and gravel sediments of the sublittoral zone are often found interspersed between rocky outcrops and in rocky fissures;

- coastal zones around the Cres and Lošinj islands, are dominated by communities characteristic of coarse sands, fine gravels and detrital bottom substrates; and

- the sublittoral on silty sediment in the eastern part of the Lošinj and Cres, and the soft-bottom community of the Kvarner Bay is characterized by Norway lobster (*Nephrops norvegicus*).

In the pelagic community neritic and oceanic (offshore) elements are mixed, especially in the south-western part of the archipelago's marine area which is under offshore influences. The economically most important pelagic fish is the sardine (*Sardina pilchardus*).

Eutrophication mechanisms

The northern Adriatic is one of the most productive regions of the Mediterranean, since it receives nutrient (mainly anthropogenic) rich freshwater from numerous rivers and streams, among which the river Po (1500 $m^3 s^{-1}$; Cati, 1981) is by far the largest. Nutrient concentrations in these rivers are at least two orders of magnitude higher than in the sea (UNEP, 1988). The discharges from Po are the primary factor governing eutrophication processes in the northern

Adriatic. In addition, they significantly influence the stratification of the water column and the general circulation of the Adriatic. This is particularly prominent during late spring when discharge rates are increased and the northern Adriatic behaves as a stratified semi-enclosed sea. The influence of discharges from minor rivers and groundwater sources is restricted to coastal zones.

Total nitrogen ($23640 \cdot 10^6$ mol y^{-1}) and phosphorus ($910 \cdot 10^6$ mol y^{-1}) inputs from all sources (rivers, sewage, atmosphere) approximate nitrogen ($38400 \cdot 10^6$ mol y^{-1}) and phosphorus ($1065 \cdot 10^6$ mol y^{-1}) quantities which are annually recycled in the northern Adriatic ecosystem, mainly in the water column (Degobbis and Gilmartin, 1990). Consequently, this ecosystem is especially sensitive to seasonal and pluriannual variations of external nutrient eutrophication pressure. Water exchange between the northern and central Adriatic represents the main mechanism of nutrient output.

River inputs significantly influence the composition and activity of pelagic biological communities of the northern Adriatic, and are responsible for a marked east to west trophic gradient (Gilmartin et al., 1990). The variability in hydrometeorological and oceanographic conditions is another set of influences reflected in the biological cycle of the region. Thus, the eutrophication of the northern Adriatic ecosystem results from the combined influence, and changing relative importance, of external nutrient input cycle (mainly from the Po River), the degree of water column stratification, and horizontal water advection, as they control and/or moderate biological assimilation and regeneration processes in the water column and at the sediment-water interface (Gilmartin et al., 1990).

In the late spring riverine discharges into the northern Adriatic increases markedly, due to melting of snow in the Alps. Simultaneously, water column stratification is intensified due to sea surface heating and freshwater runoff. Light levels and temperature favor photosynthesis, and the most strongly developed phytoplankton crops of the year occur. In the same period the circulation patterns start changing to the summer pattern characterized by cyclonic gyre. As a consequence, riverine nutrients and the products of increased primary production are distributed and recycled over a major part of the region up to early autumn. Thus the monitoring of late spring plankton bloom can provide an index of regional eutrophication and also allow an early warning of possible low oxygen events in the subsequent summer and fall, when water column stratification is more marked, even if river discharge rate is low.

The impact of freshwater nutrients on the northern Adriatic ecosystem can vary greatly in different years. For instance, in 1977 unusually high nutrient discharges from Po greatly increased the rates of production and decomposition of organic matter (Degobbis et al., 1979). Freshwater "flooded" the entire area and markedly increased the stratification of the water column. The excess organic matter sedimented and caused a higher than normal oxygen demand creating near-anoxic conditions (oxygen saturations 13-40%) in the bottom waters of the open northern Adriatic.

In some instances vertical and horizontal mixing of water can be reduced significantly by long periods of calm weather (e.g. in 1988 and 1989), thus increasing the residence time of nutrients and their effect on the ecosystem of the region (Degobbis, 1989; Degobbis et al., 1991a). As a consequence, near-anoxic conditions occurred in bottom layers, culminating in an anoxia event in November 1989 with mass mortality of benthic organisms over an area of about 4000 km^2. Interestingly, in 1989 the most critical conditions occurred in the eastern part of the open northern Adriatic, which is generally considered oligotrophic.

Periodical increased "ingression" of Levantine Intermediate Waters from the Ionian Sea represent a mechanism of natural eutrophication of central and southern Adriatic. During such events the nutrient inputs into the Adriatic may be as large as the yearly contributions from the river Po (Zore-Armanda and Pucher-Petković, 1976). Increased sardine catches (up to 20 %) were observed to follow "ingression" events, with three year delays allowing for the growth of fish.

The estimated annual inputs of nutrients in the Rijeka Bay (orthophosphate 36 t, inorganic nitrogen 1140 t, and orthosilicate 1090 t) are several times lower per km^2 than the inputs into the northern Adriatic, and research carried out in the period 1973-1981 revealed the basic oligotrophic character of the region. Generally, nutrients discharged mainly along the northern coast (Degobbis, 1983) are dispersed before having a significant impact on the marine ecosystem. Phytoplankton densities during late spring blooms, localized near freshwater sources, are at least an order of magnitude lower than in the northern Adriatic, even if nutrient concentrations are similar.

Heavy metals and organic pollutants

In the open waters of the northern and central Adriatic, including in waters around the Cres-Losinj archipelago, but with the exclusion of the narrow belt of coastal waters around Rijeka, the concentration of heavy metals (As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Zn), aliphatic and polyaromatic hydrocarbons, PCBs, DDT, HCH, lindane, and MBAS in water, particulate matter, plankton, mussels, macroalgae, fishes, benthos and sediments are on natural or global pollution levels, and generally among the lowest in the Mediterranean (Revelante and Gilmartin, 1975; Paul and Meischner, 1976; Kosta et al., 1978; Nazansky et al., 1978; Picer et al., 1978, 1981; Villeneuve and Burns, 1982; Ahel, 1984; Bregant and Catalano, 1989; Campesan et al., 1989; Giordani et al., 1989; Hieke Merlin et al., 1989; Serrazanetti and Viviani, 1989; Fossato et al., 1991; UNEP, 1988; Vukadin and Odžak, 1991). The concentration of pollutants is generally higher in the region off the Po Delta.

An exception is mercury, an element naturally abundant in the Mediterranean environment and biota. Therefore elevated levels of mercury were recorded in marine organisms, including fishes, and sediments, even in regions far from any direct anthropogenic influence, such as in the waters around the Cres-Losinj archipelago and in the open waters of the Adriatic (Gilmartin and Revelante, 1975; Bernhard and Renzoni, 1977; Kosta et al., 1978; Campesan et al., 1989; UNEP, 1989).

Radioactivity

After the 1986 Chernobyl accident, when compared with 1985 values, 100-300 times higher ^{137}Cs concentrations were recorded in the northernmost Adriatic waters (Triulzi et al., 1989). The concentrations were 10 times lower in the region between Pula and Rimini. In 1990 the levels were still up to 10 times higher than before the accident, particularly in the surface layer off the Po Delta. In this region, in addition to natural radionuclides, several "artificial" species, produced in nuclear fission processes, were also identified.

In the early seventies total beta activity and gamma spectrometry of phytoplankton, zooplankton, benthos, and sediment samples from the Cres-Lošinj area were determined. Values varied significantly among the various matrices and organism groups, but in ranges typical for the Rovinj waters (2-80 pCi/g d.w.; Jelisavčić, 1979). At least 25 "artificial" radionuclides with shorter and longer decay half-time values were determined.

PAST TRENDS

Sea level changes

Analysis of sea-level changes in the Cres-Lošinj area was based primarily on data collected between 1929 and 1939, and from 1949 onwards, at the tide-gauge station in Bakar on the mainland north of the archipelago (Fig. 4).

The mean monthly sea levels, registered at Bakar between 1956 and 1990, and the 30-year monthly averages with the corresponding standard deviations, computed for the period 1956-85, are shown in Figure 5. All values refer to the local tide-gauge datum. Significant anomalies of mean monthly values with respect to the long-term statistics are blackened. It is obvious that the anomalies occur rather irregularly. The extremely long-lasting negative anomaly, which occurred in the winter of 1988/89, is particularly interesting.

The analysis of air pressure data registered at Mali Losinj (Figure 6) reveals a complete analogy with data observed for sea-level changes, all negative anomalies in sea-level correspond to positive anomalies of air pressure, and vice versa. This holds true also for the winter 1988/89 event, when a long-lasting anticyclonal disturbance was observed over the Adriatic. A further analysis has shown that this disturbance was linked to the anomalous low sea surface temperature of the northwest Atlantic and equatorial Pacific (Pasarić and Orlić, 1992). Obviously, the event was a manifestation of global climatic fluctuations, which influence also the Mediterranean area.

The relationship and functional dependence between the observed anomalies of air pressure and sea level was investigated by regression analysis (Figure 7) which revealed a statistically significant linear fit. An increase (decrease) of 1 mbar in air pressure corresponds to lowering (rising) of sea level by 1.94 cm. This by far exceeds a simple inverse-barometer effect, because sea level responds not only to air pressure, but also to some other forcing agents (e.g. wind). Nevertheless, the observed functional relationship may have some predictive value, a forecast of anomaly in air pressure may use the linear fit to predict anomalies in sea level.

In addition to the data collected at Bakar, data from tide gauges in Rovinj and Split were also used in analyzing the trends in sea level changes. Figure 8, showing sea-level time series smoothed by a 12-month moving average, with values referring to the local tide-gauge datums, reveals considerable multi-year variability related to climate fluctuations discussed above. Such oscillations have previously been observed at Trieste by Mosetti et al. (1989).

It is of some importance to remove the oscillations in order to enable an analysis of trends and therefore a low-pass digital filter, with a cut-off frequency located at about 0.05 cpy, has been applied to the time series. The result (Figure 9) indicates linear fits to the low-passed time series. Obviously, the trends differ at the three stations: at Rovinj sea level is lowered with respect to land (-0.50 mm/year), at Bakar it rises relative to land (+0.53 mm/year), whereas at Split it decreases when observed from land (-0.82 mm/year).

In order to interpret these results, one should remember that tide gauges measure relative sea-level changes only and that the observed trends may be influenced by several factors: (a) global changes in sea-level; (b) meteorological factors; (c) large scale crustal and subcrustal movements representing regional effects; and (d) coastal subsidence which may have a local character. The observed differences between stations at Rovinj, Bakar and Split should be ascribed primarily to the latter factor, indicating that the east Adriatic coast is tectonically an active region, at least on the time scales considered here. Therefore, in making predictions for sea level changes it is important to take into account previously registered trends. Consequently, meaningful predictions should be attempted only for sites for which long time series of tide-gauge records are available.

Long-term changes in the northern Adriatic ecosystem

Some changes in the northern Adriatic ecosystem were observed from monitoring (since 1966) the primary production and nutrient cycles (CMR, unpubl. results). If these changes are real they are most likely the result of changes in anthropogenic nutrient loading and/or changes in the oceanographic regime (e.g., as related to density structure and flushing characteristics of the region) due to climate fluctuations. The relative importance of anthropogenic and natural influences is not yet known. Apparently contradictory information on anthropogenic influences were reported:

while the inorganic nutrient concentrations in the Po River at least doubled in the 1980's when compared to the 1970's (Marchetti et al., 1989), the anthropogenic phosphorus (inorganic and organic) load in the northern Italy did not apparently change (Bressan, 1986).

Although data related to changes in the rate of water exchange are completely lacking, some changes were observed in the structure of the water column. During the 1980s a summer temperature increase is evident in surface layer of the eastern part of the northern Adriatic, with a less marked variability than in the western parts (Fig. 10; Fig. 11; CMR, unpubl. results). At the same time no significant changes were observed in bottom temperatures (Fig. 11). Winter temperature (in the bottom layer also in spring; Fig. 11) appear to be lower in the more recent period. This may indicate an increased amplitude of the seasonal temperature variability. Surface salinities before and after 1980 are different in some months, but not in summer (Fig. 11). This indicates that the observed temperature increase is mainly due to increased external heat transport rather than to an increased residence time of lighter low salinity surface water, which can be additionally warmed. Bottom salinity was significantly increased recently (Fig. 11). These temperature and salinity changes led to an increase of the water column stratification degree (indicated in Fig. 11 as surface to bottom density differences) in spring, but not in summer. An increase is evident also in October, when significant changes were observed in the oxygen budget of the bottom layers.

Marked changes in the dissolved oxygen cycle were observed, both in variability and in average levels, particularly related to a more frequent appearance of near anoxic events during the autumn. In the last 20 years an average decrease of up to 40 % of seasonal oxygen saturation minimum (October/November) was observed in the eastern ("oligotrophic") part of the northern Adriatic (Fig. 12). Moreover, surface oxygen saturation in May/June increased on average from 116 % to 126 % in the last 10 years (CMR, unpubl. results).

Phytoplankton community changes in the northern Adriatic and Kvarner Region

During the 1970's, the diatoms *Skeletonema costatum* and *Nitzschia seriata* were dominant in the northwestern Adriatic phytoplankton blooms (Revelante and Gilmartin 1976). During the 1980's *N. seriata* disappeared, and was substituted by *Nitzschia delicatissima complex*, which blooms several times during the year. Moreover, since 1988 intense *Chaetoceros socialis* (or subspecies *C. radians*), species not noticed previously, occurred each year, but only during the late spring off the Po Delta (Filipić, 1990; Degobbis et al. 1991b).

In the northeastern region previously more important *Rhizosolenia stolterforthii, Chaetoceros curvisetus* and *C. diversus* were substituted by *N. delicatissima* and other *Chaetoceros* species (*C. insignis, C. affinis*), whose blooms were increasing in intensity and frequency (Fig. 13). These same *Chaetoceros* species were also observed recently (1990-1991) in the Cres-Lošinj area, but not in the period 1976-1981, when the phytoplankton composition was more variable, and in summer dinoflagellates prevailed in the microplankton fraction (CMR, unpubl. results).

While in the 1970's, in addition to nanoplankton blooms, regular late spring dinoflagellate blooms occurred (often dominated by *Prorocentrum micans*), during the 1980s their frequency was strongly reduced. Blooms became dominated by other species (*Gonyaulax polyedra, Prorocentrum minimum var. triangulatum*; CMR, unpubl. results).

Primary production changes in the central Adriatic

In the last decade changes in primary production were observed in the open central Adriatic waters, compared to the 1960's and 1970's. In these waters, based on data collected near the Vis Island, far away from any significant local anthropogenic influence, primary production rates increased from about 60 g m^{-2} y^{-1} of organic carbon in the period 1963-1980 to about 100 g m^{-2} y^{-1} in 1983-1985 (Pucher-Petković et al., 1988). Concurrently, heterotrophic bacteria biomass also increased (from 100 to 400 CFU cm^{-3}; Krstulović and Šolić, 1990). At the same time the sardine catch per unit effort increased from about 2500 to 5000 kg y^{-1} (Pucher-Petković et al., 1988).

The gelatinous aggregate problem

In the summers of 1988, 1989, and 1991 large quantities of sticky gelatinous masses occurred in the Adriatic, particularly in its northern part, floating primarily on sea surface (Degobbis, 1989; Degobbis et al., 1991b; Rinaldi et al., 1990; Stachowitsch et al., 1991). Part of this material was deposited on beaches by wind and currents, reducing their suitability for bathing. Suspended and sinking mucous aggregates (up to 3 m in maximum dimension) created serious problems for fisheries.

The phenomenon is not new in the northern Adriatic, and was described to occur periodically (for instance in 1872, 1880, 1891, 1903, 1905, 1920, and 1930; Fonda-Umani et al., 1989). Less intense localized events in the Cres-Lošinj and Dalmatian island areas were also signalized (Pucher-Petković and Marasović, 1984; Stachowitsch et al., 1991).

Polysaccharide mucus, excreted in unfavorable environmental conditions by phytoplankton and/or microphytobenthos, is the basic substance of the aggregates. In the Velebit Channel in 1983 mucus was probably produced in a benthic diatom bloom (Pucher-Petković and Marasović, 1984), but this was not the case in 1990 and 1991, when the aggregates were evidently formed in the upper parts of the water column (Degobbis et al., 1991b). This was also confirmed by a total absence of benthic diatoms (found in 1983 samples) in sampled material (CMR, unpubl. results), similarly as in the northern Adriatic (Degobbis, 1989; Fanuko et al., 1991; Revelante and Gilmartin, 1991).

A recent hypothesis links marine snow aggregation processes in the pycnocline layer (Herndl et al., 1992) with surface gelatinous mass formation, which include intermediate stages of stringers, clouds, and creamy surface layers (Stachowitsch et al., 1990). Biologically produced gas bubbles (O_2, CO_2) in the aggregates can be responsible for their rising up to the sea surface. Such an evolution was observed in May-June 1990 and 1991, when significant water column stratification was established (Degobbis et al., 1991b). Additionally, larger aggregates may be also formed by direct condensation of dispersed exudated material.

The causes of extremely increased phytoplankton mucus excretion are not yet known, but it could be related to stress conditions, due to increased variability of meteorological, oceanographic and geochemical processes observed in the last years in the northern Adriatic. As an example, in 1988 and 1989 stratification was established early during a warmer than usual winter and was very marked in summer (Degobbis at al., 1991a). Nutrient concentrations were below averages and horizontal advection was reduced (Degobbis et al., 1991c). Phytoplankton photosynthesis might have been stimulated during long periods of calm and sunny weather, but its growth then limited by reduced nutrient availability. In that cases phytoplankton cells may excrete excess polysaccharide mucus in surrounding water, forming aggregate nucleus, whose formation was favored by the reduces water turbulence.

The impact of gelatinous aggregates on the western Istrian coastal region was marked in August 1988 (Precali et al., 1989). Beaches were contaminated with large quantities of gelatinous masses transported by light wind ("maestral") blowing from the sea towards the land, which is typical for summer. At the end of summer, a significant flux of aggregates to the bottom caused selective mortality among sessile benthic organisms, particularly between 5-20 m depth. Since the oxygen content was not critically low at the sediment-water interface, death was probably due to mechanical effects (Zavodnik et al., 1989). In contrast, in 1989 and 1991 no significant contamination of the Istrian coastal waters occurred, because of prevailing wind atypically blowing from the land to the sea (Degobbis et al., 1991b). Aggregates started to form also in June 1990 (in the Cres-Lošinj area surface gelatinous layers appeared), but the process was interrupted by a series of meteorological perturbations, characterized by windy weather (alternately "bora" and "scirocco").

POSSIBLE MODIFICATIONS OF THE CRES-LOSINJ MARINE ENVIRONMENT DUE TO LONG-TERM CLIMATIC CHANGES

The discussion of possible changes in the Cres-Lošinj marine environment, presented in the next text, is based on the following assumptions, derived from the results of mathematical model predictions for temperature and rainfall changes in the Adriatic area:

- A moderate air temperature increase in the Cres-Lošinj area (1.5-4°C up to 2050, and 2-6°C up to 2100), similarly as in the greater part of the Adriatic, would occur. These changes would be more marked during the summer, less marked during the winter, and near average during spring and the fall.

- Rainfall changes in the Cres-Lošinj area would be of low significance. Some increase is expected in winter and spring, more marked in the northern part of the area, some decrease in the summer and fall, more marked in the southern parts of the area.

- A significant rainfall increase will occur in the Kvarner watersheds during the most part of the year, except during the summer, when a slight decrease is predicted.

- No significant rainfall changes will occur on average within the northern Adriatic watersheds (Po and minor rivers, except some of the northernmost ones), but some reduction is expected during summer, and an increase during winter. However, an increase of the outflow of the northern Adriatic rivers may occur due to the expected melting of Alpine glaciers (e.g. Warrick, 1989).

While a specific knowledge on the Cres-Lošinj marine environment is extremely scarce, some relevant results, related to changes in the marine ecosystem during the eighties, were obtained from historical data series collected in some stations in the northern and central Adriatic. These results were useful to improve the reliability of the change predictions for the Cres-Lošinj marine environment, described in the following text.

Prediction of mean monthly sea levels at Bakar

In order to prepare prediction of mean monthly sea levels at Bakar to the year 2100, it has been assumed that the meteorological, geological and tectonic contributions to the observed trend would not change in the forthcoming century. Moreover, a recent estimate of the rate of global sea-level rise has been taken into account (+ 1.8 mm/year; Douglas, 1991), as well as the predicted changes in the rise (Stewart et al., 1990). The exercise gave the following estimates for future mean sea-level rise at Bakar (with respect to the year 1980):

year 2050: + 8 cm (min), + 75 cm (max),
year 2100: + 14 cm (min), + 194 cm (max).

The prediction is shown in Figure 14, along with the previously observed trend. Again, sea levels refer to the local tide-gauge datum.

Figure 14 depicts also mean monthly sea levels registered between 1956 and 1990, as well as their prediction, based on the assumption that standard deviation of mean monthly values around the trend would not change (dashed lines indicate limits inside which mean monthly sea levels should appear with a 68-percent probability). In the case that a forecast of air pressure would be available, results shown in Figure 7 would enable a real prediction of mean monthly sea levels to be prepared - not just a simple extrapolation of their statistics.

Considering the prediction of Figure 14, it should be pointed out that its value is limited by (a) assumption that the meteorological contribution to the trend from the 1956-90 interval would be preserved in the following century, and (b) prediction of global sea-level change, which depends on a number of factors and is quite unreliable. Moreover, it should be stressed that the prediction concerns mean monthly sea levels, whereas particular sea-level heights may be considerably greater, or smaller, being influenced by processes (storm surges, tides ...) which are obscured while computing mean values. Yet, the prediction may be of some use, particularly in a worst-case analysis.

Waves

Waves in the area are directly related to the wind regime changes. Since there are no indications on these changes, it is difficult to say anything about the future wave conditions in the area.

Currents

The insufficient present knowledge makes an accurate prediction of future changes of marine current regimes very difficult. This imposes a serious limitation on the prediction of other changes in chemical and biological processes, which are strongly affected by water dynamics and exchange rate.

Gradient currents in the area may accelerate in the winter, due to additional freshwater inputs. Moreover, due to combined effects of greater freshwater inflow and enhanced stability of the water column, residual currents may intensify in the warmer part of the year, too. This would most probably support a permanent organization of the summer current field in several circulation cells, and a reduction of the water exchange between the northern and central Adriatic.

Changes in morphological configuration of the coasts and bottom are not expected, except those derived from sea-level rise, which will be probably small. Related to this no noticeable changes in tidal currents would occur.

Wind-driven surface currents, which are probably the most important water exchange mechanism in the Kvarner area, are directly related to the wind regime. It is expected that they will be reduced, if synoptic atmospheric systems shift to a more northerly paths, and the wind frequency and force consequently decrease.

Sea surface temperature

Existing data from the Rijeka Bay and northeastern Adriatic indicate that yearly cycles of air and surface sea temperature are quite similar, even if of different amplitude. Thus, it may be expected that during the stratification period (approximately from May to September) the sea surface temperature will increase almost as the air temperature. Significantly, the mean surface temperature for August during the eighties was about 1.5 °C higher than during the seventies (CMR, unpub. results). Salinity averages did not differ significantly, indicating that the heat content increase was due mainly to radiation and air temperature increases, and not due to an increased residence time of lower salinity water on the surface.

The temperature of deeper layers would be much less affected, since data show their much slower heating during the stratification period (e.g., Degobbis, 1981). Some of the heat, accumulated in the surface layer, is transferred to deeper layers at the end of the summer and fall when vertical mixing becomes significant again.

Winter sea temperatures should change much more markedly than in summer, due to lower air temperature changes, as well as to significant vertical and horizontal mixing, which should distribute the heat increment throughout the water column.

Stratification/mixing

The water column stratification and vertical mixing depend strongly on density differences due to temperature and salinity changes. Freshwater input influences salinity in a higher extent than evaporation and direct rainfall contribution to the sea surface. The influence of the freshwater input is more marked in the northern part of the Cres-Lošinj area, where at the same time the surface temperature is on average lower than in the southern parts.

In spring, increase of surface temperature, much more marked than for the deeper layers, would enhance the water column stratification and reduce vertical mixing. Due to expected increase of freshwater input, the water column stability will be additionally enhanced, particularly in the northern parts of the Cres-Lošinj area. In contrast, during summer, decrease of rainfall may partly compensate, or, in the southern parts even overcome, the temperature effects. This, however, will not occur if the area would be influenced to a greater extent by freshwater outflow related to the melting of Alpine glaciers.

Possible wind regime changes would significantly affect water column mixing, only temporarily increasing/decreasing column stability and surface layer temperature with simultaneous decrease/increase of the surface layer thickness.

Frontal systems

Frontal phenomena of estuarine type, , very variable and shortly persistent in time, are formed in the area but no data on them are available. Some frequency increase of their appearance could be expected, if the freshwater input would be increased.

Salinity and coastal water chemistry

Surface salinity will be reduced during the greater part of the year, due to freshwater input increase from the Kvarner watersheds and other areas. In summer the northern Adriatic surface waters can spread more intensively to the Kvarner region, being carried by the several-cell circulation system - which presumably would protrude farther south.

Freshwater nutrient inputs (particularly nitrate and orthosilicate) could also increase and influence surface layer phytoplankton activity. Some increase in other compound concentrations, including pollutants, may also be expected. At the present, it seems that pollutant levels in the Kvarner freshwater, particularly in underground waters, are generally not critical.

Coastal flooding and other episodic events

Low level areas, like Punta Križa, will be flooded in relation to intensity and frequency of southern and eastern winds, as well as absolute sea-level rise.

Primary production

An increase of primary production may be expected to occur in the Cres-Lošinj area, due to temperature rise and increased freshwater nutrient input, particularly in spring, when environmental conditions are optimal. Bloom persistency and intensity also depend on wind mixing of the water column. If anticyclonic conditions would tend to prevail in the atmosphere, blooms would be favored. As a consequence of increased phytoplankton activity water transparency would be reduced and water color will shift to green gradations.

Already during the eighties a significant primary production increase was observed in the central Adriatic (Pucher-Petković et al., 1988), waters of which mainly influence the Kvarner area (Degobbis, 1983). In the northern Adriatic in addition to an increase of surface temperature in summer, changes in the composition of phytoplankton community was observed, as well as an increased intensity of the blooms off the Po River delta and increase of near anoxic events, particularly in the eastern parts of the northern Adriatic, in which oligotrophic conditions prevail. These events are probably related to change in circulation patterns of the bottom waters, and a decrease of water exchange rates, possibly due to climatic changes (Degobbis et al., 1991a, 1992). In addition, since 1988 large quantities of excreted organic matter are produced, from which, during summer, in conditions of calm weather and marked stratification, large mucilaginous aggregates were formed in the water column, which partly, after aging and compactation, raised to the sea surface forming extended gelatinous layers (Degobbis, 1989; Degobbis et al., 1991b). These phenomena also occur in the Kvarner Region, but with a lower intensity and persistency. The reason of increased phytoplankton excretion is still unknown, but it may be related to an increased environmental condition fluctuations, probably due to climatic changes. If this is correct, these phenomena may be repeated also in the future with higher frequency.

Although it is believed that diatoms prefer colder waters, in the last years diatom blooms, as a difference of dinoflagellate blooms, were regularly observed in the northern Adriatic even in late spring and summer (Filipić, 1990; Degobbis et al., 1992). This implies that shifts from diatoms to dinoflagelates, as it is widely believed, may not necessarily occur in the Adriatic with rising temperature. This would be favorable for grazers, which would benefit from increased primary production, without significant changes in their composition, preventing possible interruption of the marine food chain.

A primary production increase imply some oxygen demand increase during remineralization of organic matter. This demand increase would not have serious consequences for the marine ecosystem of the Cres-Lošinj area, which is essentially oligotrophic and well aerated. However, a significant bottom oxygen saturation decrease would occur in summer, if the water exchange rate would be reduced, due to increased weather stability and increased influence of low-salinity northern Adriatic waters. This can influence the benthic community composition, favoring those organisms which better tolerate oxygen level fluctuations.

Positive effects of increased primary production could be cancelled in case that produced organic matter ends in form of mucous or in non edible part of food web (e.g. *medusae, pteropodae*).

In 1989 several beaches along the Istrian coast were closed with net barriers, which effectively excluded gelatinous masses transported onshore in a few cases by the "Maestral". These barriers also appeared to be useful in keeping bathers safe from jellyfish and boats. Since the gelatinous aggregate hypertrophy is a periodical phenomenon, the development of more sophisticated specific protection or cleaning systems is probably not economically rational.

Benthic communities

In conditions of the stepwise rise of mean annual seawater temperatures of 2-3 °C, and the rise of sea surface level of 50-60 cm, the occurrences of the following phenomena are highly probable:

1. Littoral communities characteristic for rocky shores in mid-littoral and supralittoral zones will be stepwise displaced to a higher level following the sea level ascending. Because of the same geomorphological features of limestone slopes which are discontinued from land hill peaks till some ten meters depth in the sea, the microhabitats populated by littoral organisms will not be altered. But an unpredictable alteration in the height of the upper mid-littoral and supralittoral belts, and the adlittoral zone at sites exposed to stormy NE wind bora (Lovrić, 1971) can occur if general meteorological (climate) conditions will affect the actual wind regime. Minor changes in height/breadth of communities belts also can be expected at any change of mean wave heights affected by tidal and wind currents alterations, especially in inter-island straits, coastal gorges, and cliff fissures. In this respect, most conspicuous alterations are expected in *Catenella repens* and *Chthamalus stellatus* populations.

2. In the geological past, in dependence of global climatic fluctuations, in the actual Mediterranean region several alterations occurred in species composition and distribution patterns of marine flora and fauna of a different origin (Fredj, 1974). The evidence of these phenomena, among others, is the presence in the Adriatic Sea of many algal and animal taxa which are considered to be of boreal or tropic origin (Giaccone, 1978; Gamulin-Brida et al., 1987). Therefore, at the increase of mean sea temperature of 2-3 °C, it becomes a reality the expansion of the actual thermophile populations and the introduction into the Cres-Lošinj area of new species which previously had been noted only in the southern parts of the Adriatic Sea and in the Mediterranean. In both cases, the diversity and abundance modifications and successions in benthic assemblages will take place. It sounds, however, rather a speculation to name any plant and animal taxon which in reality can be considered. It is only the matter of presumption that the littoral banks of corallinaceous alga *Lithophyllum lichenoides* perhaps will acquire in dimensions like those in the Central Adriatic, that the sea urchin *Arbacia lixula* in the upper infralittoral will take the dominance over *Paracentrotus lividus*, and that the sea star *Hacelia attenuata* populations will reach the Lošinj aquatorium. Also the phenology of marine organisms, especially of seaweeds surely will be influenced but at present any prediction in this matter seems to be precocious.

3. At sea temperatures higher than 22 °C the eelgrass *Posidonia oceanica* beds will suffer regressive successions or even will be exterminated: these phenomena are based on physiological demands of the plant (den Hartog, 1970). An immediate and direct consequence of the general regression and disappearance of eelgrass beds is the lack of a very important habitat niche of marine organisms to which eelgrass leaves and stems are ground support, or to which dense eelgrass settlements represent an excellent shelter and spawning habitat. Furthermore, dense surface beds suppress wave actions forming a functional lagoon or shelter belt along the beach (Pérès & Picard, 1964). A further trouble of an eelgrass depletion will be a decrease in benthic primary production and a consequential crucial diminution of organic detritus input into deeper layers (Pérès, 1961), which can give rise to unpredictable alterations in benthic communities in infralittoral and circalittoral zones and through food chains finally also affect the demersal fish stocks (ichthyocoenoses) characteristic for various kinds of the sediment bottom.

4. The temperature raise in the marine environment perhaps will cause the alteration in main sea current system in the Cres-Lošinj aquatorium especially in the parts bordered on the Kvarner area and the high sea. Each retardation in water masses exchange will promote the increased sedimentation of fine particles thus indirectly triggering the successive alterations in autochthonous benthic communities. In all probability, in small depth the siltation of fine sandy bottom will benefit the expansion of the seagrass *Cymodocea nodosa* beds, which locally perhaps will occur in account of the eelgrass *Posidonia oceanica* beds (Pérès & Picard, 1964). However, the eventual increased sedimentation of inorganic detritus in the area considered perhaps will not be intense enough to give rise to expansion of muddy trawling grounds important in demersal fish and Norway lobster fishery.

5. It is well known that seasonal migrations of the sardine (*Sardina pilchardus*) and sprat (*Sprattus sprattus*) in the shallow North Adriatic, in the late autumn and in winter before all are due to optimum temperature requirements of fish at their reproductive period (Gamulin & Zavodnik, 1961). The northern Adriatic most important spawning places of these fish were located in the southern Kvarner area for sprat (Teskeredžić, 1983) and offshore the Unije and Susak Islands for sardine (Gamulin, 1954). Therefore one can presume that the warming of the sea will evolve the northward displacements of sardine and sprat spawning places. Referred to these phenomena, dislocations of actual fishing grounds are possible.

The greatest changes, due to rising temperature, would occur in the upper littoral zones. Some organisms may benefit, and some not, so the species and genetic diversity will be reduced and/or stressed.

Fisheries productivity and mariculture

A possible higher primary production may result in higher pelagic fisheries productivity. It is impossible to predict which species will benefit out of it.

Conclusion

Man can hardly control climatic and oceanographic conditions. He can, however, moderate the anthropogenic load, primarily in the northern Adriatic and Kvarner watersheds, and decrease eutrophication and related phenomena in the marine environment. Intervention effects are quite unpredictable since the critical nutrient inputs, below which undesirable events should not occur, are not yet known. Thus, monitoring and specific researches of the northern Adriatic ecosystem should be continued and intensified.

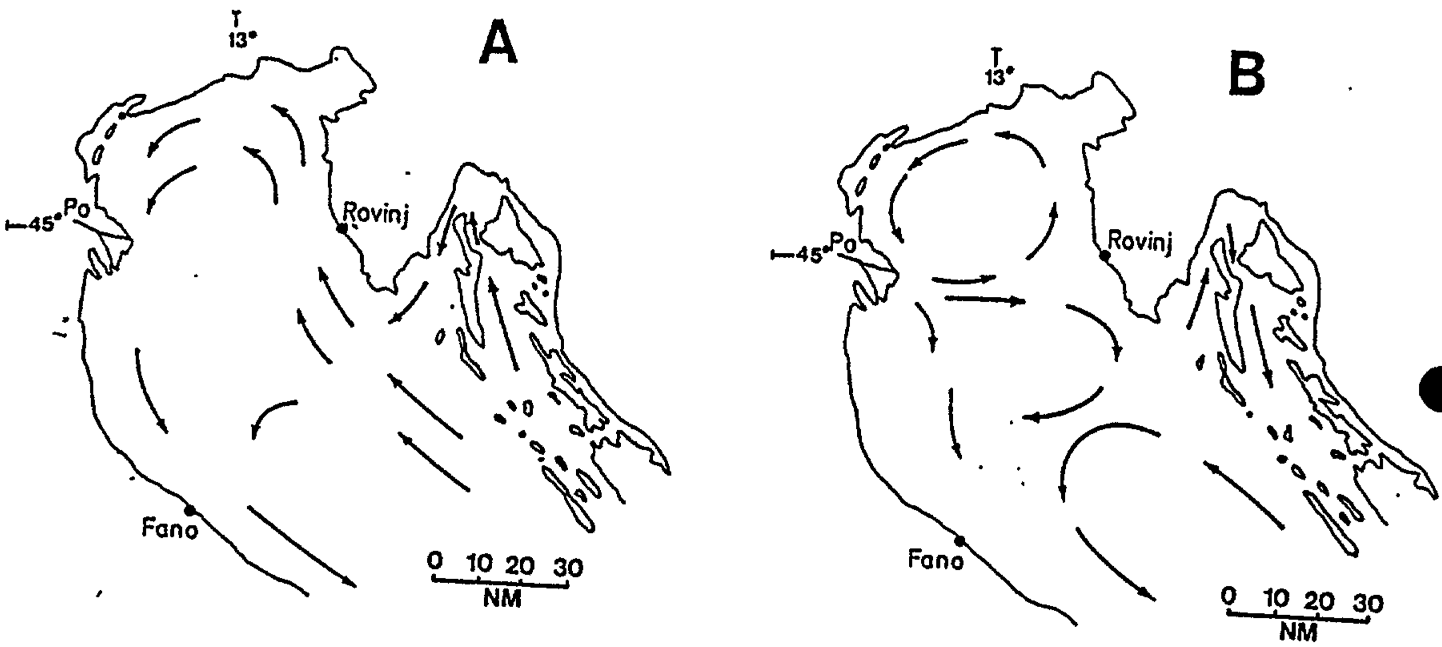


Figure 1 Current patterns in the northern Adriatic
A - fall/winter; B - spring/summer

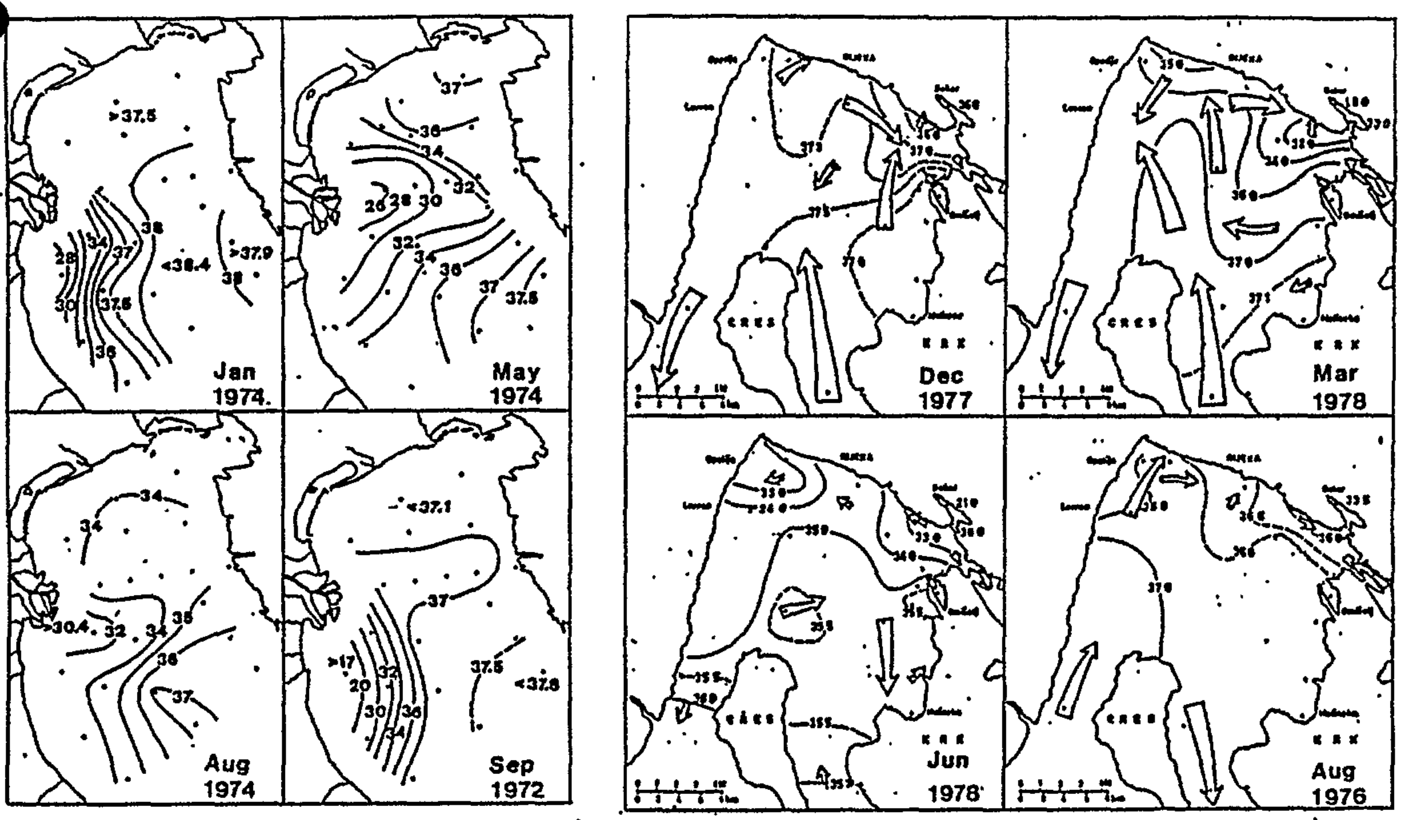


Figure 2 Surface salinity distribution in the northern Adriatic (left) and Rijeka Bay (right).
The arrows indicate vector average current direction

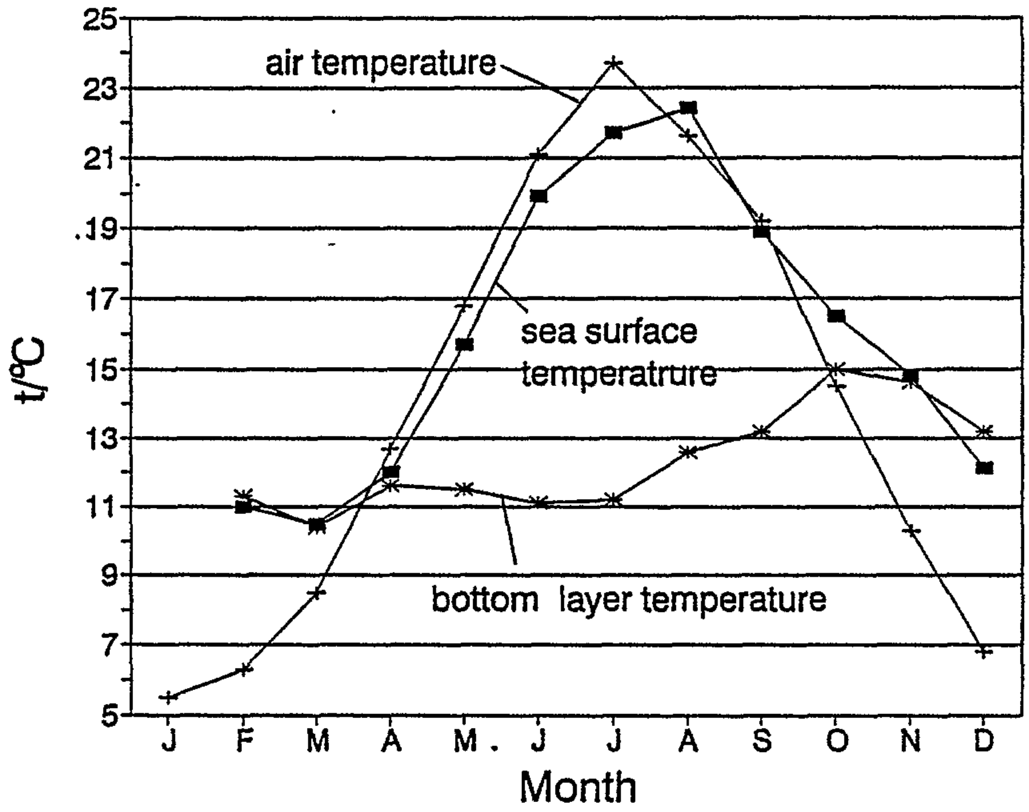


Figure 3 The seasonal temperature cycle (monthly mean) in Rijeka Bay

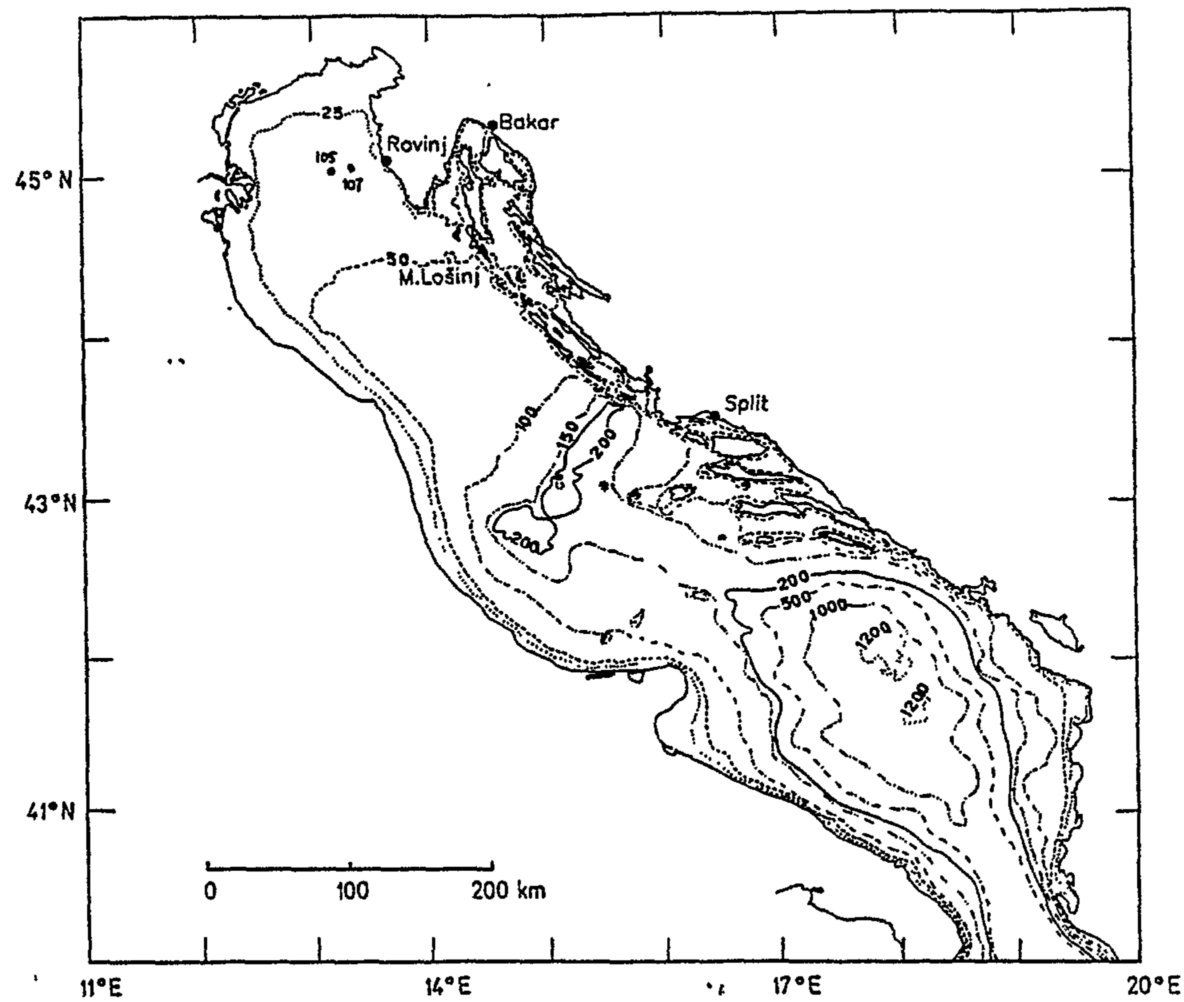


Figure 4 Topography of the Adriatic Sea and position of measuring points

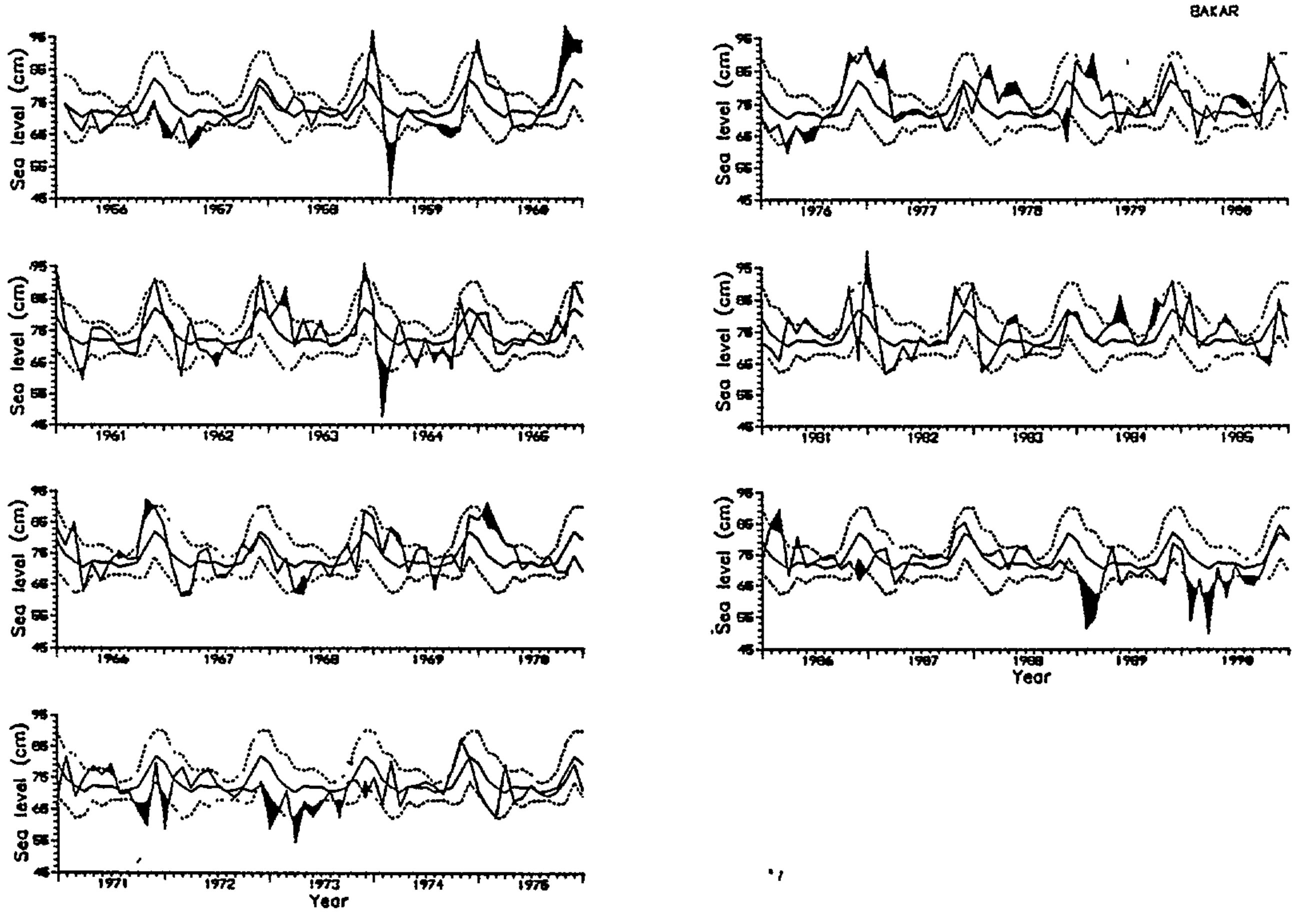


Figure 5 Mean monthly sea levels at Bakar, superimposed on the 30-year averages and corresponding standard deviations. Significant anomalies are blackened

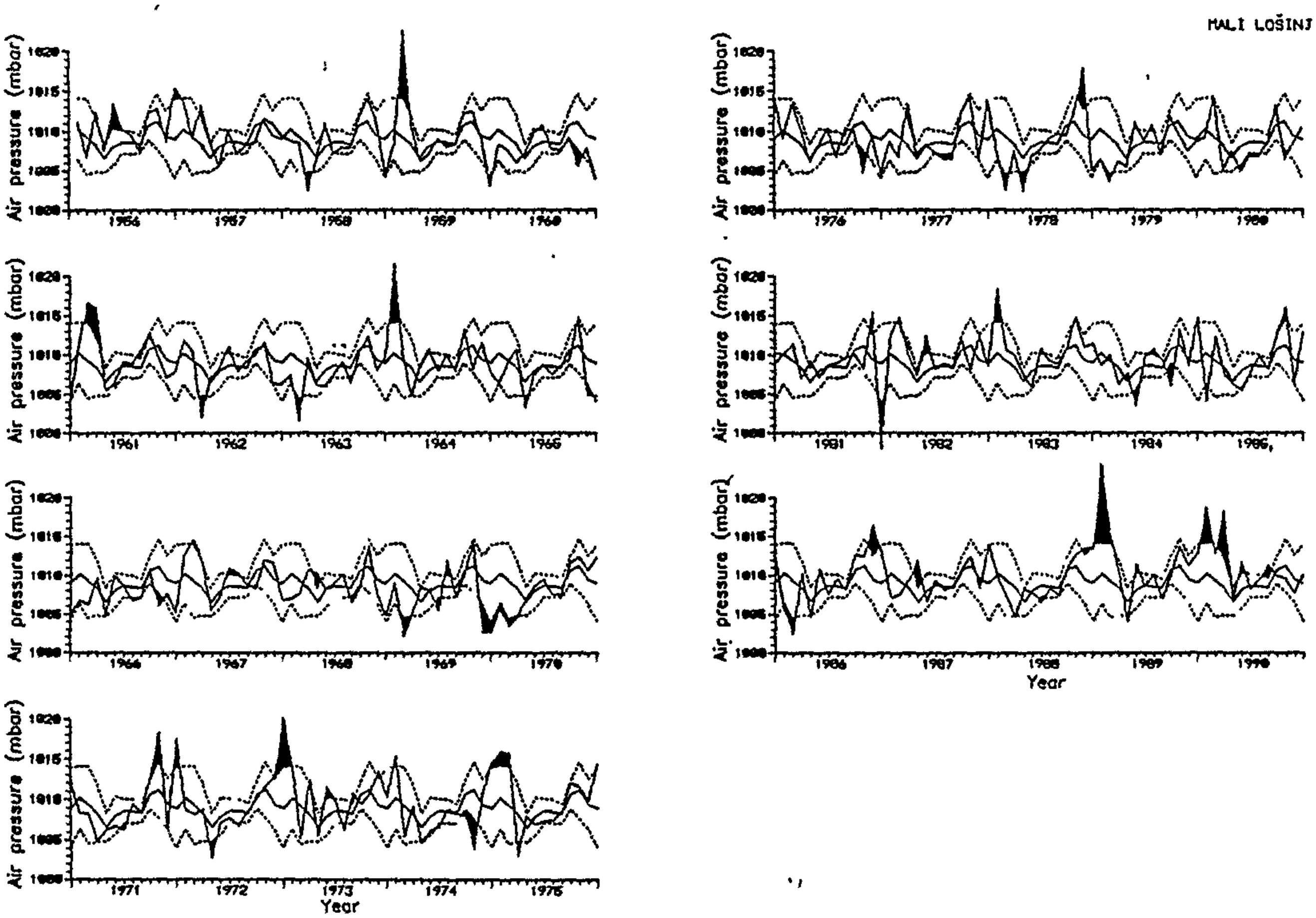


Figure 6 Mean monthly air pressures at Mali Losinj, superimposed on the 30-year averages and corresponding standard deviations. Significant anomalies are blackened.

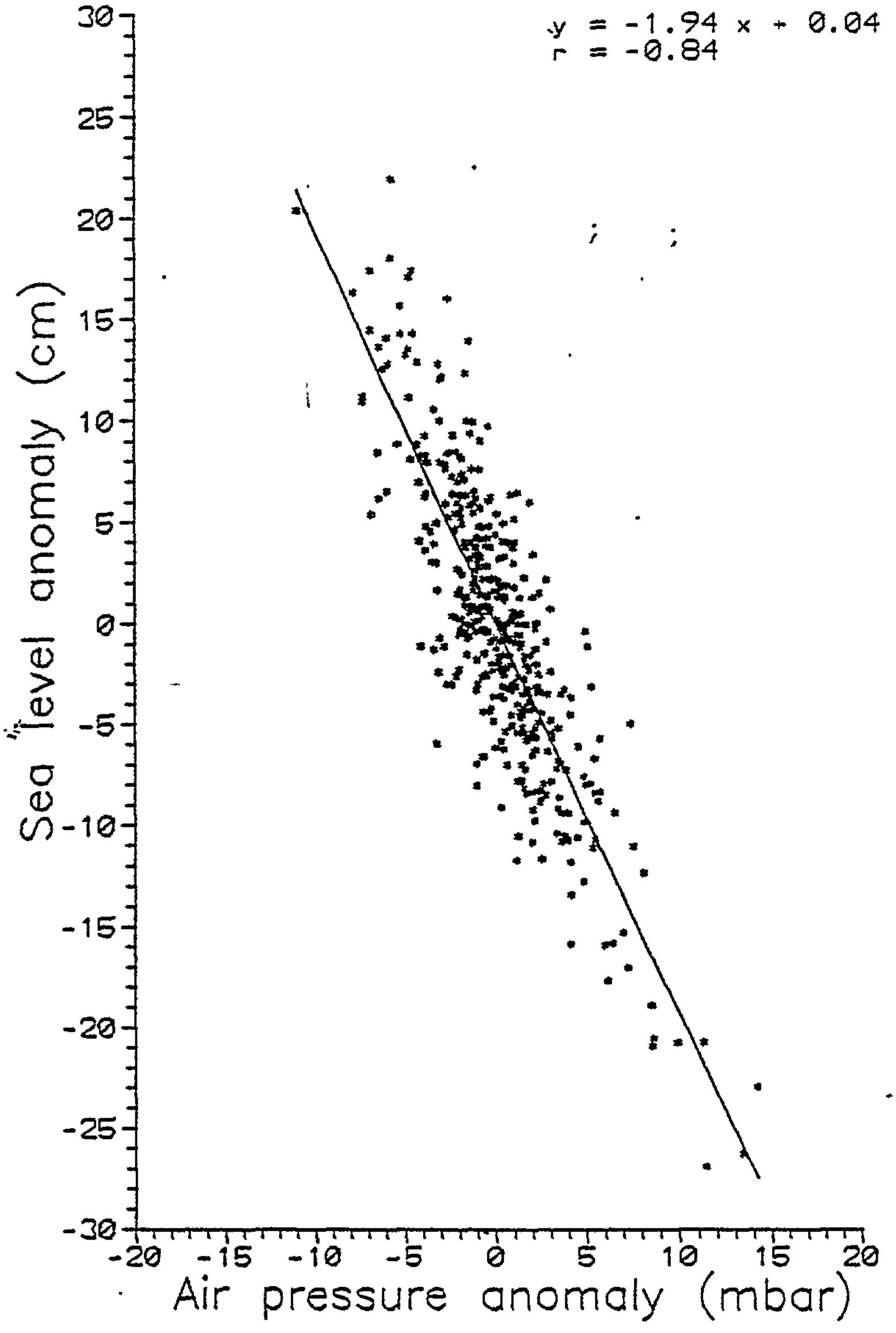


Figure 7 Result of regression analysis of the anomalies of air pressure registered at Mali Losinj and anomalies of sea level, recorded at Bakar.
The data were collected over a 35-year interval (1956-90)

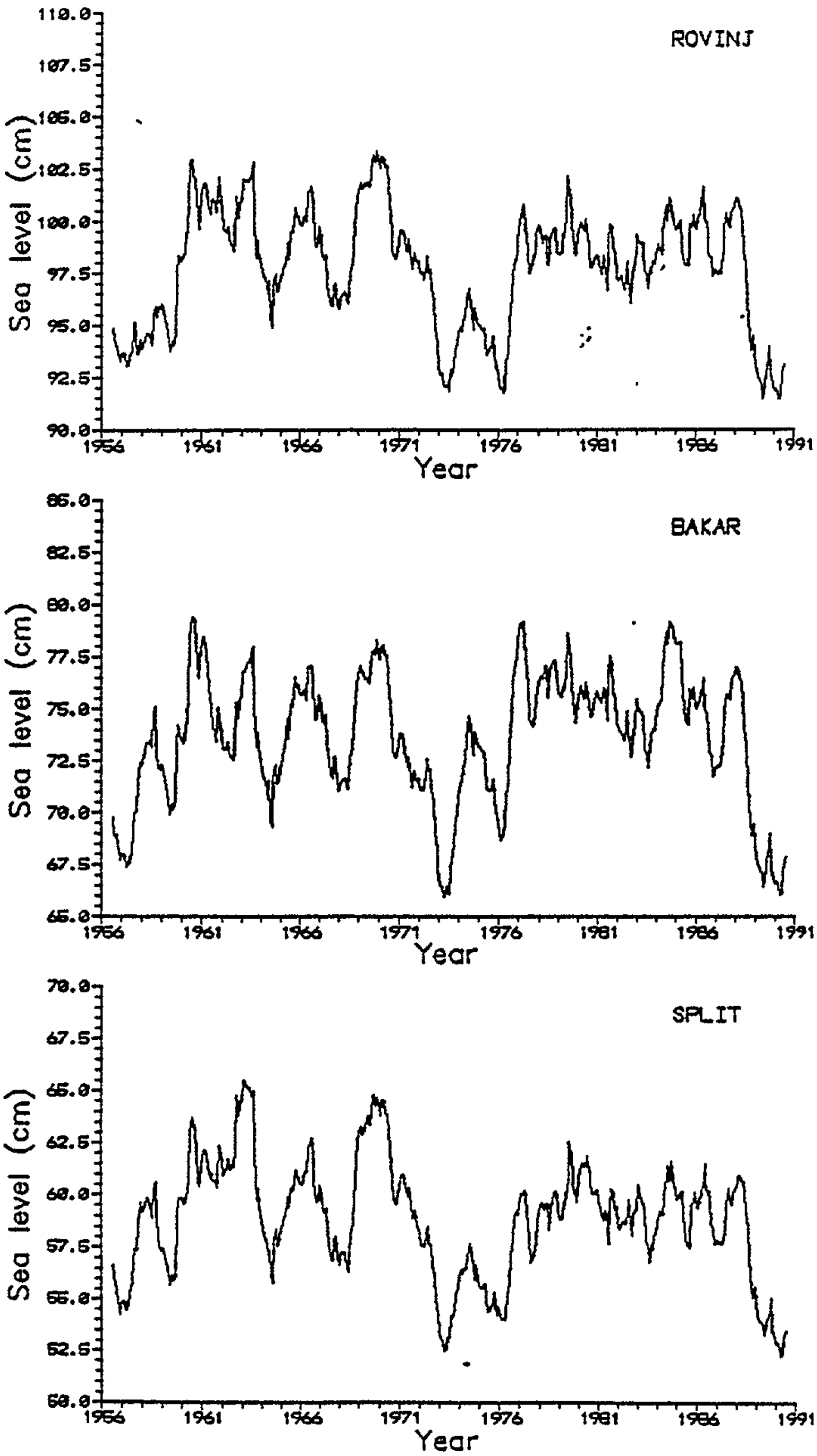


Figure 8 Sea levels registered at Rovinj, Bakar and Split, and smoothed by a 12-month moving average

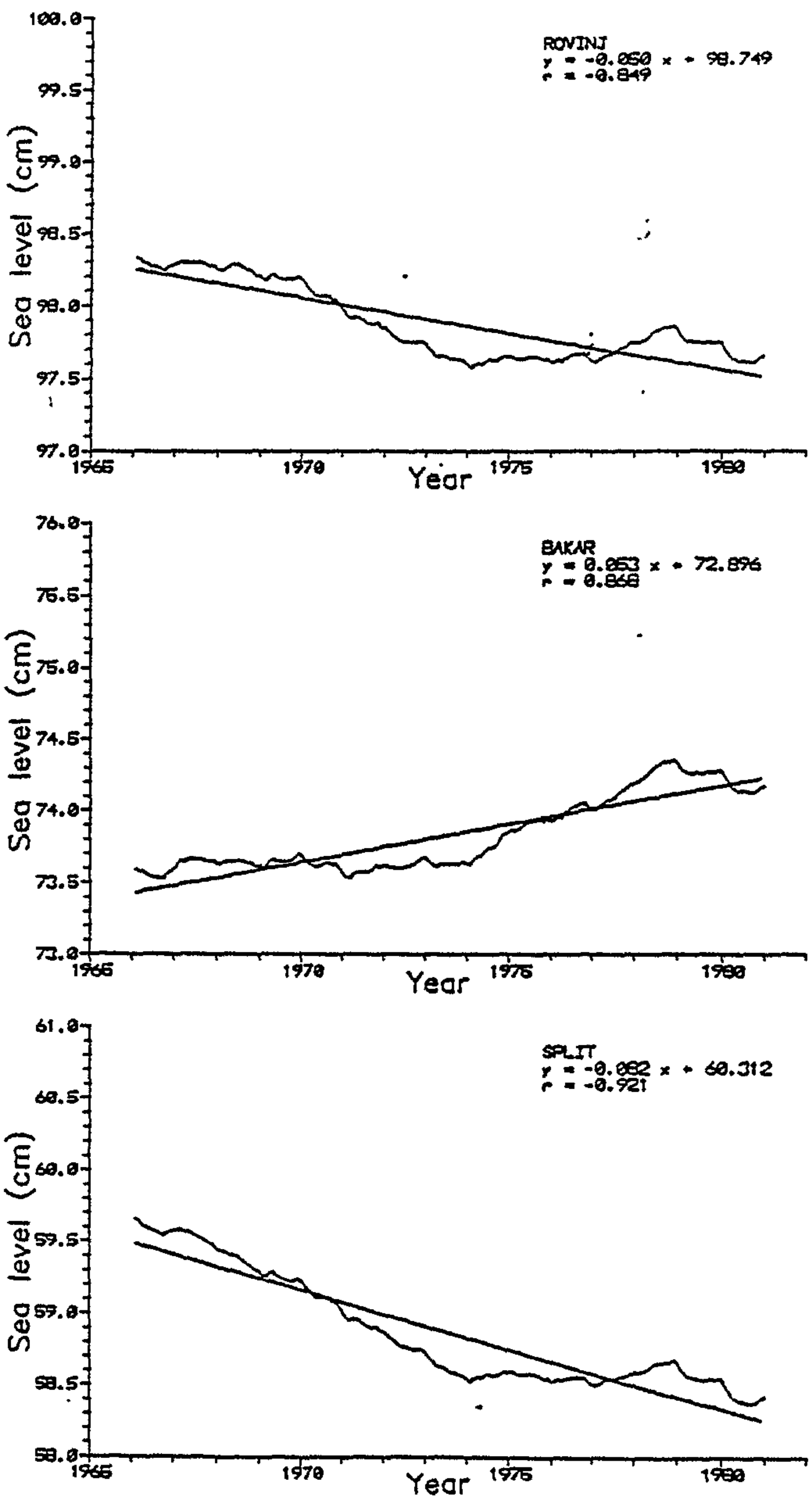


Figure 9 Low-passed sea levels for stations Rovinj, Bakar and Split.
Also shown are the corresponding regression lines.

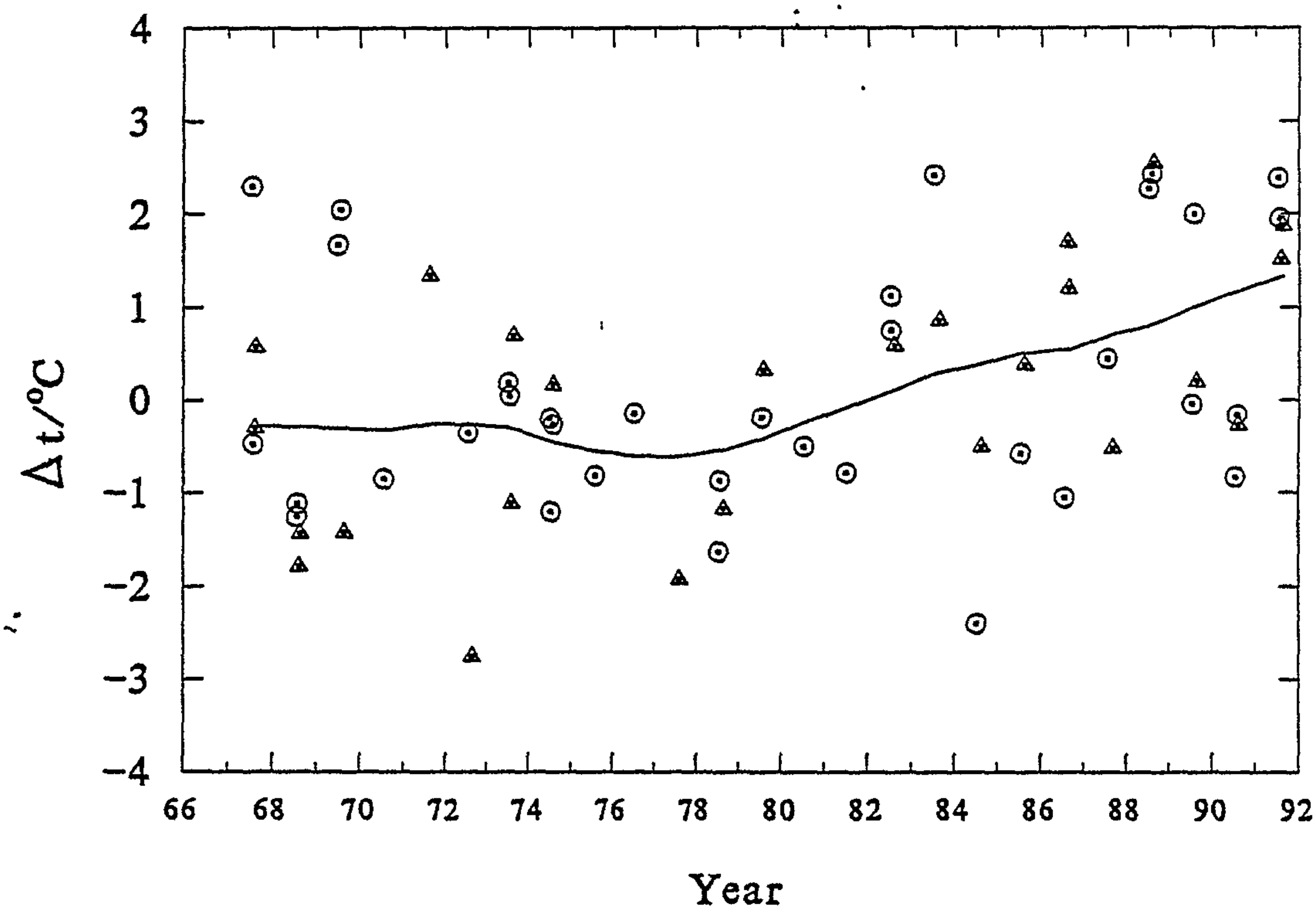


Figure 10 Surface temperature anomaly (t from long-term average) trend in July ( ) and August ( ) at station 107 (Fig.4).

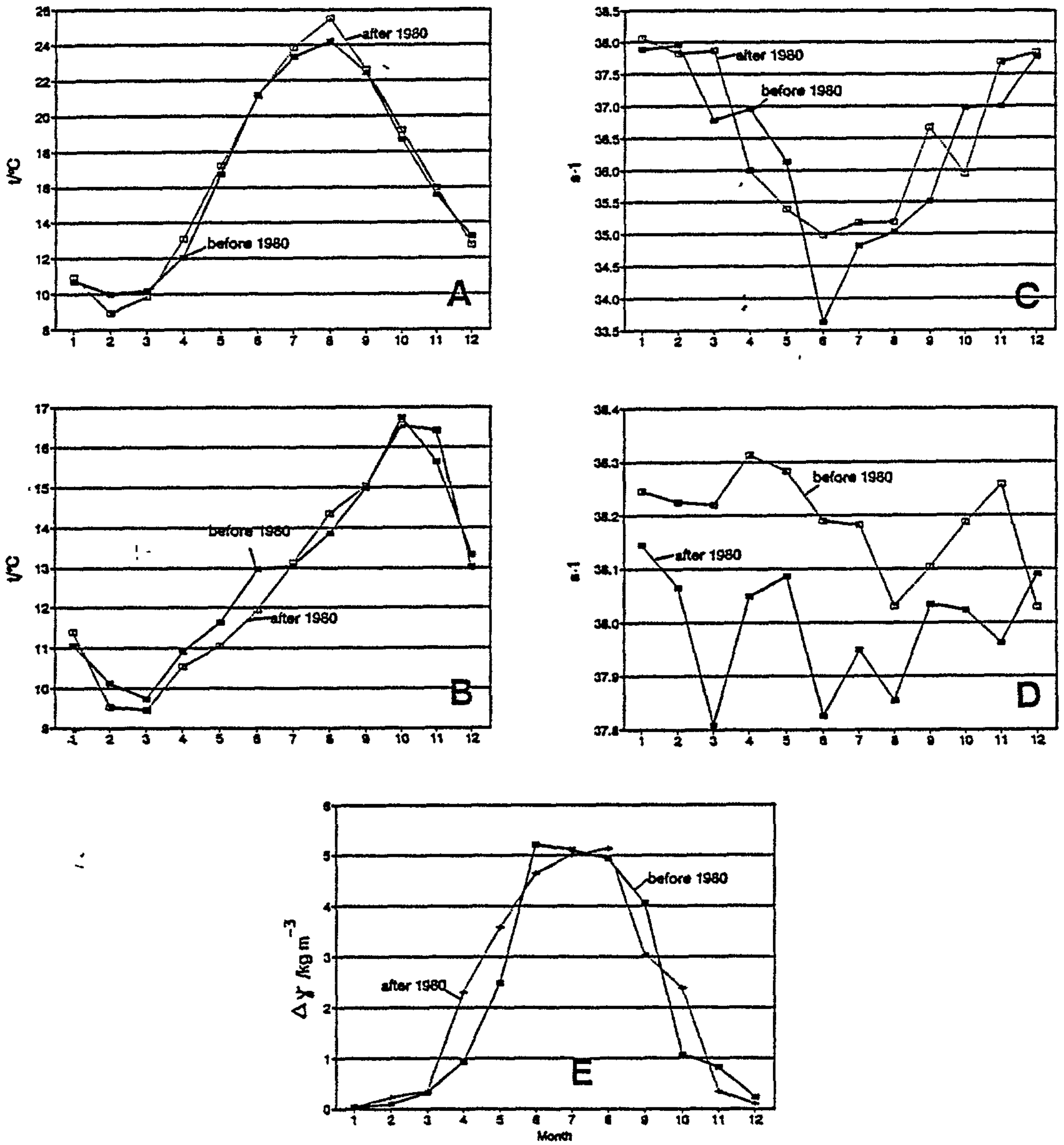


Figure 11 10-year average seasonal changes (before and after 1980) of surface temperature (A), bottom temperature (B), surface salinity (C), bottom salinity (D) and bottom to surface density difference (E) at station 107 (Fig.4).

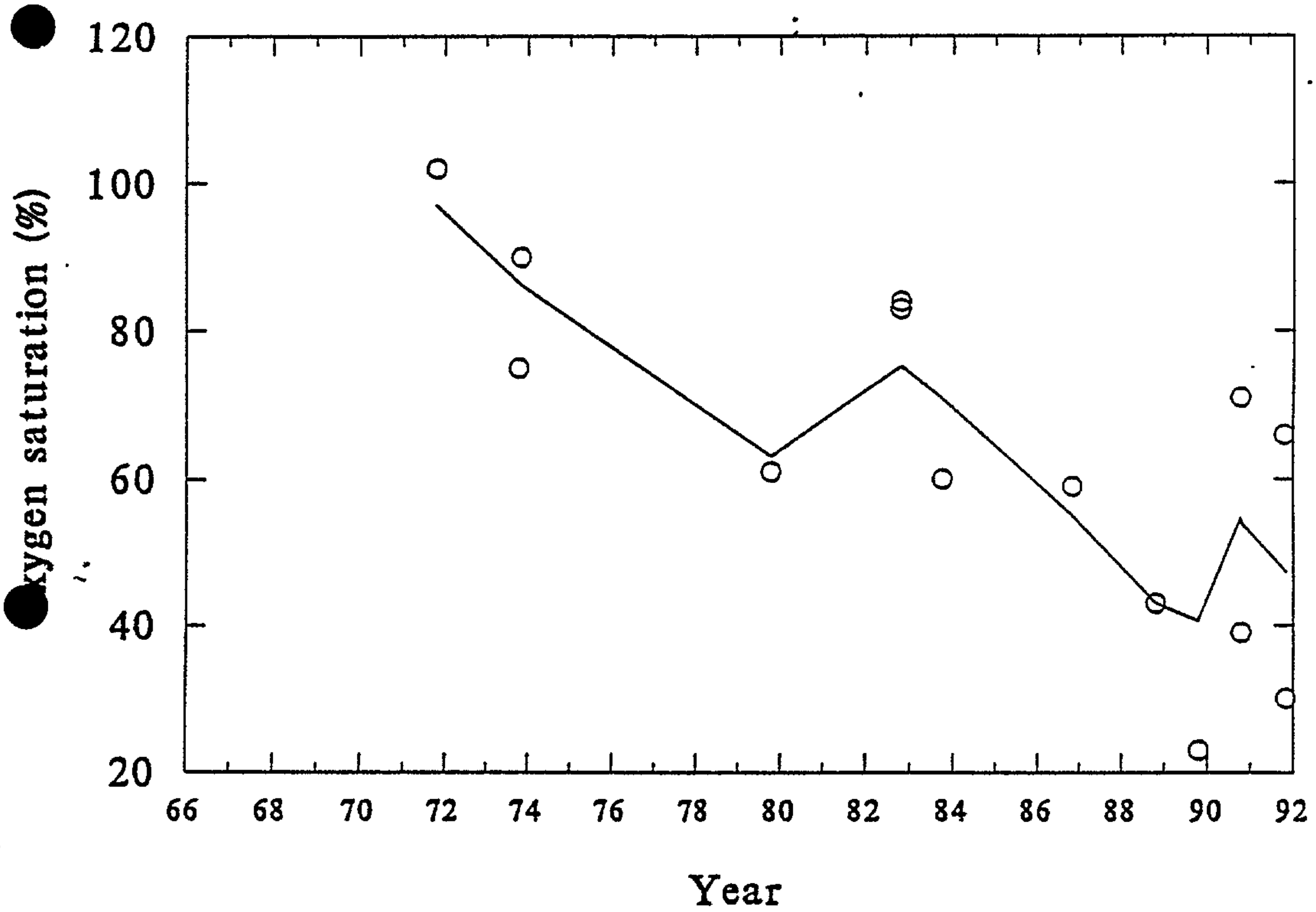


Figure 12 Long-term bottom oxygen saturation in October at station 107 (Fig.4).

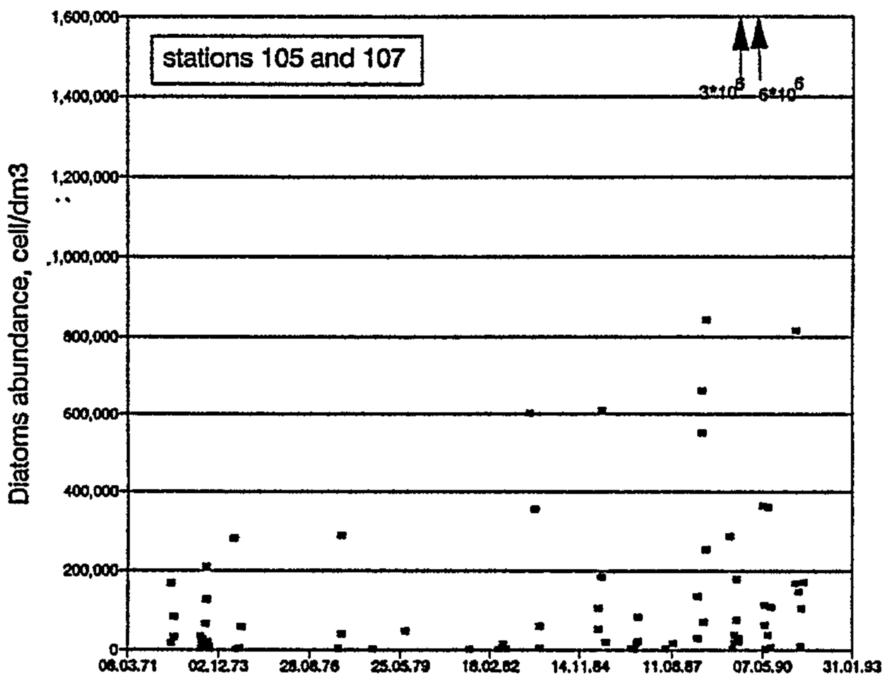


Figure 13 Long-term surface diatoms abundance at stations 105 and 107 (Fig.4).

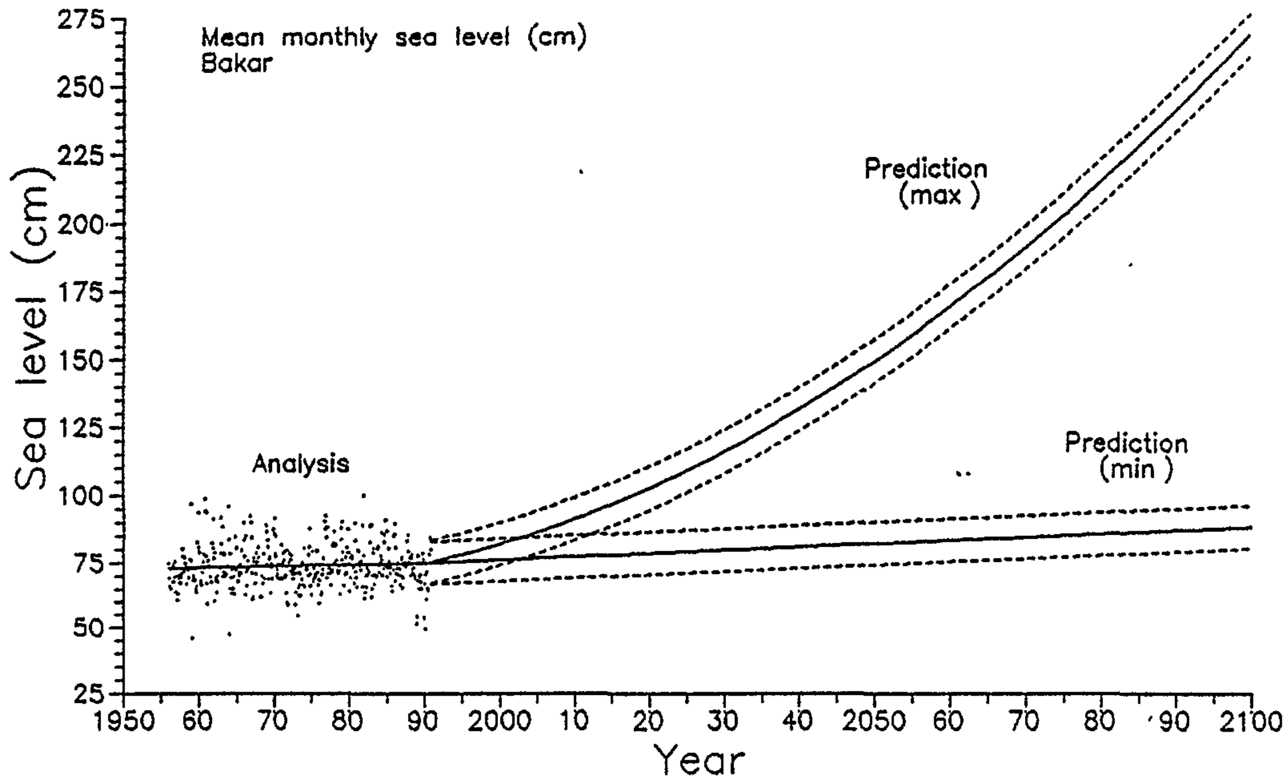


Figure 14 Analysis and prediction of mean monthly sea levels at Bakar.
Full lines indicate previous and possible future trends, dot marks mean monthly sea levels recorded between 1956 and 1990, whereas dashed lines denote limits inside which mean monthly sea levels should be expected with a 68 per cent probability.

2.6 Managed Ecosystems

2.6.1 Agriculture (Ugo Toic)

Influence of climate changes on the agricultural production

Agriculture on Cres-Losinj archipelago is nowadays poorly developed and of mainly extensive character. Considering favourable characteristics of the land in the sense of agricultural production on the area of 513 km^2 which is the exact expansion of the archipelago, 38% (19653 hectares) belongs to agricultural areas out of which only 4,8% (950 hectares) can be used for intensive production. 68,4% of this area (650 hectares) are divided into seven larger pieces of land and the remaining 31,6% (300 hectares) are small pieces, plots, scattered over the whole community, some of them being on quite inaccessible regions. Not even 50% of this land is being cultivated and the situation is even worse on other inaccessible and rocky agricultural areas.
They are progressively abandoned and so once cultivated land turns into grassland or even macchia and wood. Such a situation is also the result of the population decline after the Second World War and the desertion of agriculture with the development of tourism and light industry. The only agricultural branches which succeed to survive are sheep breeding and olive growing while others continue to disappear.

According to the scenario of the climate change in the North Adriatic area, which was made by the Hydrometeorological Bureau of the Republic of Croatia, using previously experienced relations between climate modifications and agriculture, we shall try to consider the influence of new climate changes on the present agriculture of Cres-Losinj archipelago.
It is expected that until the year 2050 the temperature shall increase for 1 °C yearly all over the archipelago. Summer temperature shall be 0,1 - 0,2° higher than its average global value, especially in the north part of the archipelago. If we observe this change as an isolated element and suppose that it would be followed with the same increase of precipitation, the conclusion would have been that this would hardly have any effect on the agriculture at all. The climate of the northern part of the archipelago would reassemble the south one, while the climate of the south part would equal the climate on one of the middle Dalmatian islands of today (for ex. Hvar). However, as we have already mentioned, the increase of the temperature values increase evapotranspiration, and no change in the yearly precipitation quantity is expected but a slight increase in the northern part and a slight dicrease in the southern part of the archipelago. The picture is even worse if we consider that precipitation in summer months is 7% lower and is happening in the period of plant's increased need for water and when evapotranspiration is maximal. Furthermore, high evapotranspiration results also from the relative level of humidity which in such circumstances decreases as well as from strong winds expected in summer months. We have to know that precipitation is the element of climate which is dependent to many variations, therefore the reality often differs a great deal from the picture we get by collecting many years' average statistics. Studying the Cres island it became clear, as you have noticed from mentioned above, that by observing monthly disposition of precipitations and the Walter climatodiagram, we do not register a period of dryness but in fact it is present from time to time. Therefore, considering all the facts we can forecast that in the year 2050 a dry period will be rather frequent and this will undoubtedly have strong effect on development and organization of agriculture production.

Reduction of precipitation in autumn shall not be very important considering plants' smaller need for water and the quantity of precipitations being high. During the period till the year 2100 the situation shall be even worse, the temperature increase is namely expected to be 3 °C and the precipitation dicrease more than 15%. It is important to mention that this deteriorated change of conditions for the agricultural production applies only to the summer period while in the same time the increase of the temperature level and precipitation quantity during winter time is expected to be positive.

Climate changes as forecasted above shall have the following effects on Cres and Losinj agricultural branches:

FRUIT GROWING: In economic terms the most important fruit sorts on these islands are olive and cherry-trees. Olive-trees are grown on 550 hectares (about 120.000 of trees), mostly around the Cres town. The mode of growing is extensive, without soil cultivation which is one of the most efficient agrotechnical measures to dryness protection. Olive is a fruit subject to alternated production where dryness has an important role. Yearly oscillations in olive production already exist in present climate conditions, therefore we could presume that they will, with climate changes, be manifested even in greater extent. Survival of olive-trees in such conditions comes not in question but is certain that the economical validity of extensive growing will be reduced.
Today, olive-trees growing together with sheep breeding and vegetable growing presents one of the main income side sources from the agricultural production for the inhabitants of these islands; however, in future they will exist only if favourable climate factors would lead to massive crop. The influence of dryness could be decreased, as we have already mentioned, with soil cultivation which is almost impossible to obtain with machinery in existing olive-groves. Therefore it will be necessary to make future olive-groves on such ground with deep soil where machinery can be used.
Cherries ripe before summer dryness which therefore is not dangerous for them if trees are planted in deeper soil where there are still humidity reserves.
Considering other sorts of fruit-trees, dryness will affect those sorts that do not come from mediterranean climate conditions, those that are planted in the superficial layer of the soil and ripe after the period of dryness. This means that when forming orchards one should take care to choose those sorts that ripe early (before the dryness period) and have no great demand on low temperature sums during the resting period of the plants. It is important to know that higher temperature lead to earlier vegetation; when average yearly temperature increases for 1 °C, vegetation starts 5 days earlier. That will enable planting of early sorts.

Effects of dryness could be prevented or reduced by mulching with natural or synthetic covers, using the system of microirrigation as well as basis more resistant to dryness.

VEGETABLE growing is mostly developed around the towns of Cres and Veli Losinj and on Unije where vegetables are cultivated for market sale while on other places they are cultivated only for domestic needs. The total area cultivated with vegetables covers about 30 hectares.
Vegetables have great water demands therefore long periods of dryness make problems especially to vegetables in summer time.
Nowadays gardens are watered mainly from the Lake of Vrana, in dry periods however this is not going to be possible anymore so the only alternative lies in building or getting reservoirs to collect water over winter periods. They would be used in winter periods in the same way as they are used in fruit growing, that is with mycroirrigation. To reduce evaporation from the earth there are different sorts of plastics folios and other materials that are being used in vegetable growing and they are a good protection against dryness.

Temperature increase in winter months will most likely enable cultivation of early vegetables in greenhouses as well as in the open, therefore the accent shall be removed from the summer to the winter production. It is expected that better conditions will also improve greenhouse flower growing which does not exist at all. Vegetables which ripen in summer months will have to be provided from other places unless the irrigation problems are solved satisfactorily. Otherwise, farmers are going to loose a great deal of income they used to get directly from the vegetables market where vegetables were sold with high prices to the tourists. The question remains whether the production of early vegetables or flowers could replace such income.

SOIL CULTIVATION - Except for potato growing, The "Jadranka" enterprise is the only one to continue soil cultivation on the field of the island Unije. That kind of cultivation is not profitable and a change of production has already been planned. Considering potato growing the temperature increase shall enable it's earlier planting as well as ripening; this will help to avoid the dryness period. To succeed in such a plan means to plant early sorts of potatoes.

VINE GROWING - The entire vine growing area covers about 30 ha and we can conclude that vine growing is badly developed.

People grow grapes nearly exclusively for their own needs. Exceptions make newly set plantations on the Susak island with intensive cultivation and for the commercial purpose. It is the characteristic of the grape that it can fight dryness successfully if it is planted deep in the earth because of well developed root system. The soil should be very porous so even deeper layers could absorb water while the retention capacity remains small which enables a plant to get as much humidity as possible. Only sandy Susak has such kind of soil while other islands with thin lays of soil do not provide successful wine production.

The influence of dryness shall be reduced with correct soil cultivation or in other words, when forming new vineyards it will be necessary to take care of the depth of the soil, of using base layers resistant to the dryness and choosing the adequate cultivation treatment.

SHEEP-BREEDING - On these islands sheep breeding is the most developed breeding branch as well as the most developed branch of agriculture itself. On the 13500 hectares of grassland there are 25000 sheep. Sheep are bred in extensive way, that is they are tended in open during the whole year with minimal or none supplemental feeding. However, it is obvious that dry periods to-come shall reduce forage production and supplemental feeding will be a necessity. The same happens to natural and artificial water supply points and additional, more frequently water provisions shall be needed. On those grasslands that are without trees probably shelters will have to be constructed to protect the sheep in the shadow during hot summer months.

Sheep breeding exists mainly in villages with regretfully less and less inhabitants, many grasslands are slowly turning into macchia and, if nothing essential is undertaken, this agricultural branch shall soon regress so that climate changes will have almost nothing to affect to.

Increasing of the temperature and the greater amount of humidity in summer months shall cause earlier and quicker evolution of noxious insects and diseases; high temperature reduce the evolution period, therefore more generations appear in the same time span.

Sea-level rise and its effects on agriculture

The land treated for the agricultural production can be divided in two main groups. In the first group there are holocene colluvial accumulations in areas with karst fields, valleys, coves and basins such as Bale, Cunski, Cikat and other smaller fields. Their acreage is relatively small extending from 10 ha to several thousands m^2, all being out of the zone of direct influence of the sea. The area of Piskel on the south of the Cres bay is an exception: it is situated close to the sea level and it has rather high level of underground waters. The sea level rise of about 10 cm would affect the level of underground waters and their saltiness, while higher rise would result with an overflow in extension of more than 1 ha.

The second group belongs to the pleistocene lignified sands of Susak, Unije field, south-east parts of Vele and Male Srakane and Kurila area. They are of about 100 ha or more, spread by the sea, several meters above the sea level. Therefore the sea-level rise can only affect their outskirts. This can happen on the Unije field where frequent rough weather and the sea-level rise can cause stronger negative effects or erosion processes.

The Unije field has its own natural water sources that can be used as drinking water for the inhabitants as well as for irrigation of the small vegetable planted area. This sources are becoming brackish and there is a possibility that the sea-level rise leads to such saltiness that will make the water useless.

Conclusion

It has been noticed that after the Second World War the agricultural production on Cres-Losinj archipelago is in constant decline so that at present olive-growing (120.000 trees on 550 hectares) and sheep-breeding (25.000 sheep on 13.500 hectares) are the main agricultural branches left.

Areas that are suitable for intensive production make only 4,8% out of the whole agricultural territory, and 50% of it are not cultivated at all. The deserted agricultural territory is turning into grassland or macchia. There is some vegetable production on the island of Unije, around the towns of Cres and Veli Losinj.

Vine growing is mostly developed on the island of Susak and cultivation of land again on Unije.

Temperature increasing and rainfall reduction during summer months will cause negative effects on the agricultural production. This means that the existing olive production could become even more unstable as it is now. Speaking about sheep-breeding it is expected that the production of feed on grasslands shall be reduced and the need of water supplies shall increase and will have to be brought to the natural or artificial watering-places.

Reduction of water supplies will be strongly felt in vegetable growing that cannot exist without it.

It is therefore necessary to build or provide water-collecting reservoirs that will help to irrigate orchards and vegetables gardens with mycroirrigation systems. It will also be necessary to proceed with mulching either with natural materials or plastic folios. The fruit-trees will have to be planted in such lays of soil that are resistant to dryness. Assortment of fruit sorts and vegetables will have to be adapted to new conditions which means that the plants will have to be chosen among such sorts that ripe before the dryness period. Vegetable growing will have to be oriented toward early-ripe production in the open or in greenhouses that could also be used for flower-growing. Sheep-breeding will have to be supported with supplemental feeding and more water supplies. Degraded grassland and also that which is turning into macchia shall slowly be reforested to keep humidity and produce richer soil.

A part of water-tax should be intended for building or providing water-collecting reservoirs as well as for agricultural land protection from further erosion process. New sorts of fruits and vegetable plants will have to be researched to find those that could be brought up in new climate conditions.

There are not many inhabitants of Cres-Losinj that occupy themselves with agriculture and we can conclude that climate changes are not going to provoke drastic consequences in the socio-economic status, the agriculture being nothing more than a side income source.

2.6.1.1 **Table 1**

Monthly/Yearly Temperature Average on Cres and Mali Losinj (1952-1975)

Meto Stato	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
Cres	5.7	6.4	8.8	13.3	17.4	21.4	24.1	23.5	19.5	15.0	10.8	7.4	14.4
M. Losinj	7.3	7.6	9.4	13.0	17.2	21.1	23.8	23.6	20.4	16.8	12.3	9.1	15.1

2.6.1.2 **Table 2**

Frequency of Absolute Minimal Air Temperatures Under 0°C on Cres and Mali Losinj 1960-1975)

Meteo station	I	II	III	IV	XI	XII	yearly
Cres	15	14	8	1	8	14	60
M.Losinj	8	6	3	-	-	3	20

2.6.1.3 **Table 3**

Number of Cold Days (Min.Temp.Under 0°C) on Cres and Mali Losinj (1952-1975) and their Monthly Distribution

Meteo station	I	II	III	IV	XI	XII	together
Cres	12	14	2	-	-	2	30
M.Losinj	4	6	1	-	-	-	11

2.6.1.4 **Table 4**

Average Precipitation Quantity on Cres and Mali Losinj

Meto Stato	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
Cres	98	81	82	78	71	68	69	79	97	113	146	114	1096
M. Losinj	90	77	75	63	65	52	49	64	106	95	142	98	976

2.6.1.5 **Table 5**

Average Cloudiness (0-10) on Cres and Mali Losinj (1952-1975)

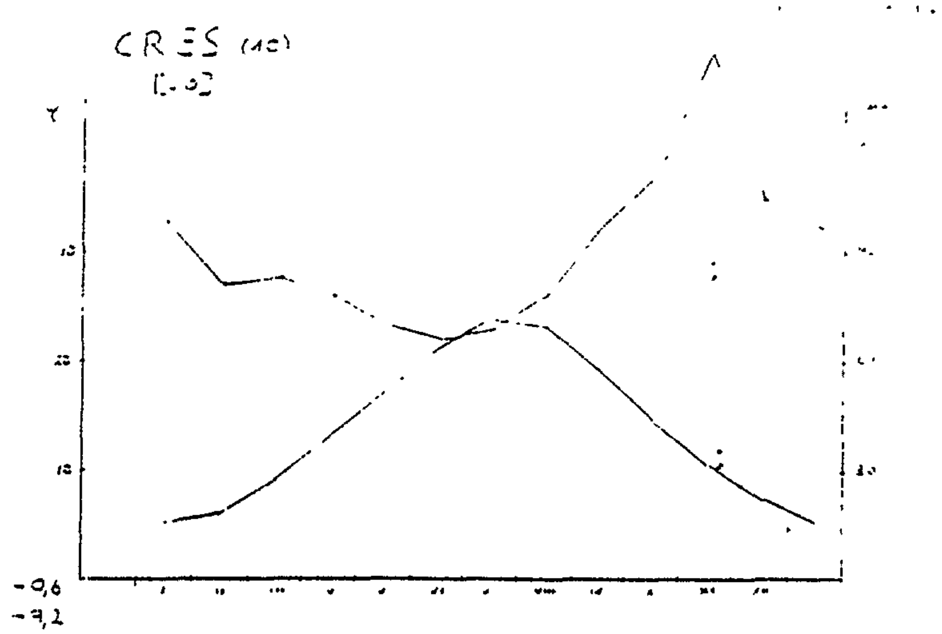
Meto Stato	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	yearly
Cres	5.9	5.7	5.5	5.2	4.5	4.5	2.9	3.0	3.6	4.4	6.1	6.2	4.8
M. Losinj	6.0	5.7	5.7	5.1	4.6	4.2	2.7	2.9	3.7	4.4	6.2	6.3	4.8

2.6.1.6 **Table 6**

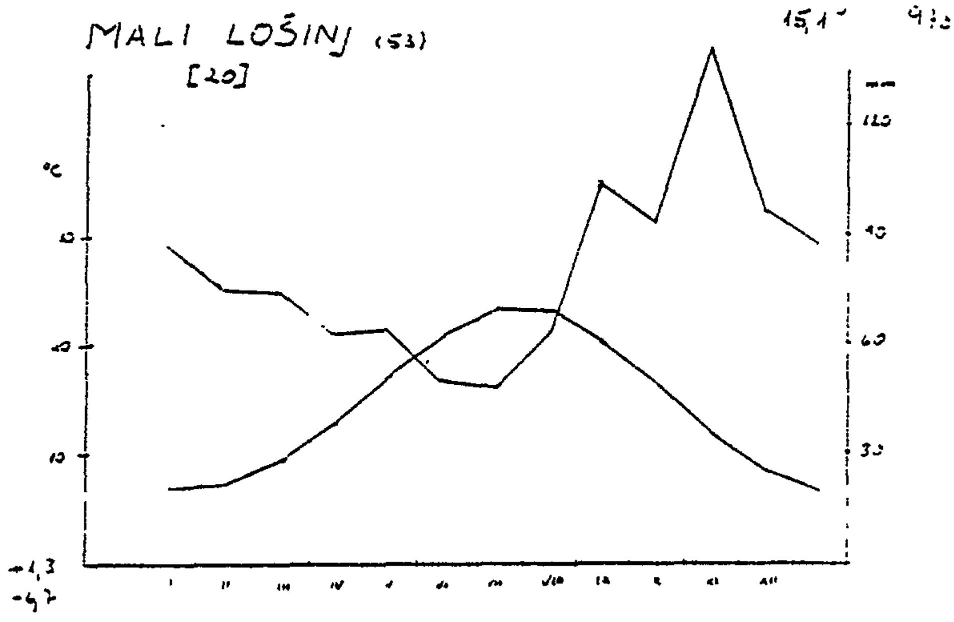
Distribution of Wind Directions in Rijeka and Mali Losinj (1952 - 1975)

Meteo station		N	NE	E	SE	S	SW	W	NW	Together	Calms
Cres	Aver.	146	303	75	138	76	87	96	169	1090	5
	%	13.4	27.8	6.8	12.6	6.8	8.0	8.7	15.4	99.5	0.5
M. Losinj	Aver.	151	235	57	101	130	96	87	49	910	185
	%	13.8	21.6	5.3	9.3	11.9	8.8	7.9	4.5	83.1	16.9

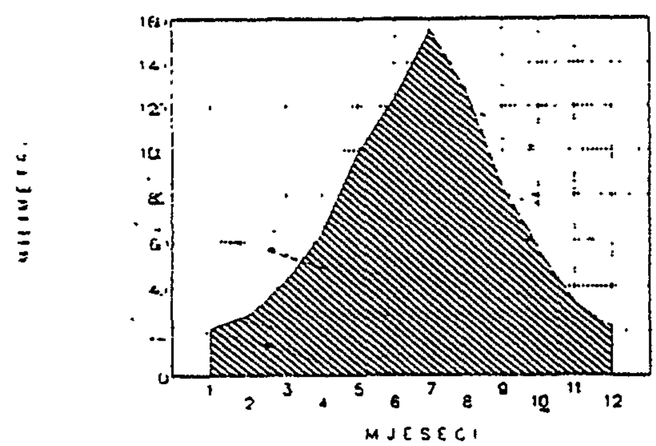
2.6.1.7 Walter's Climate Diagram for Cres (1952-1971)



2.6.1.8 Walter's Climate Diagram for Mali Losinj (1952-1971)



2.6.1.9 Referent Evaportranspiration



2.6.2 Fisheries

Past trends

As mentioned before the Cres-Lošinj aquatorium is not homogeneous. Thus, regarding the fishing potentials and particularly concerning the quality of fish from the bottom communities we can identify several fishing zones. The so called "small blue fish" (pilchard *Sardina pilchardus* Walb., sprat *Sprattus sprattus L.*, anchovy *Engraulis encrasicolus L.*, mackerels *Scomber scombrus L.* and *S. japonicus* Houttuyn and other species) are caught all around the Cres-Lošinj archipelagos. Schooling behavior, seasonal and daily migrations and their presence in various sectors depends on various hydrographic and biogenic factors. Some of these species (pilchard and sprat) spawn in the Kvarner bay from the early autumn to late winter and the fishing period of highest intensity does coincide with spawning (Gamulin, 1954, 1975; Teskeredžić, 1978; Kačić 1982). In the past, along the coast of Cres several tunny-fishing nets (tunare) were installed to trap tunas when migrating along the coast as it was used in many parts in the north Adriatic channels and coastal bays (Basioli, 1984). During the last decades tunas almost disappeared but recently there are some indications of their come back in the Adriatic, but picturesque "tunare" irreversibly disappeared, and new fishing technologies are used.

Regarding bottom fishing two main zones are distinguished. In the north, along the rather steep coast of Cres, fine mud bottom communities are distributed already near-by the coast at the depth of 50-80 m. In the south, around the islands od Lošinj, Unije, Srakane, Susak and Ilovik the bottoms are shallower with many rocky banks and sandy sediments prevail in between. Bottom fish like european hake (*Merluccius merluccius L.*), whiting (*Gadus merlangus L.*), angler (*Lophius piscatorius L.*), skates and ray-fish, cat-sharks and others, langoustine (*Nephrops norvegicus L.*) octopods (*Ozaena moschata* Lam.) squids (*Loligo sp.* and *Ommatostrephes sp.*) and others are cached with trawl nets primarily on the fine mud bottoms. In the Rijeka Bay it is not aloud to use trawl nets, but it is very diffuse to catch langoustine with traps. In the south zones the presence of many species of the so called "white - rocky bottom fish" is more significant and several types of gill nets are used to catch several species of sparids, serranids, labrids and other "white - rocky bottom fish" of high commercial quality.

Fishery statistics for the Cres-Lošinj area and in general, are not accurate. As reported, the yearly amount of fish landed in the region varies between 400-500 metric tones, of which nearly 5 to 15 % concerns the "small blue fish" (Morsko ribarstvo 1989, 1990, 1991). Most of the given data represent the quantity of fish landed through the official domestic market organizations, while a great part of fish captured by istrian and south dalmatian fishing boats, that is landed in the respective regions is not reported for the Cres-Lošinj area. Figures about landing of "small blue fish" are more accurate, while the records of high quality "white - rocky bottom fish" are not credible, because these fish are preferentially sold aut of the official market. Some rough, unauthorized estimations indicate that the annual catch in the whole Cres-Lošinj area amounts to about 1500 metric tons of "small blue fish" and 800 tons of "white fish" (Balenović, personal estimation), a figure that is not far from the actual situation.

About 150 medium and 400 small size fishing boats operate in the area of the archipelago.

In the Cres-Lošinj aquatorium there are not any protected fishing area, but in the physical plans (Ozretić et al., 1988) and in the novel Low about marine fishery several areas were anticipated.

Expected effects and most vulnerable systems and activities

Either bottom or pelagic fish stocks depend on a rather complex system of hydrographic and bionomics factors. Initially it appears improbable that the anticipated temperature and sea level increase will have any significant effect on fish stocks. By speculation one can expect that the anticipated climatic changes could provide even positive effects on the presence of single fish species in the region. One can also suppose the immigration of some species from the south Adriatic, presumably the greater amberjack (*Seriola dumerili* Risso) and other tunny fish species. However, bottom and particularly pelagic communities could be ultimately altered due to presumable changes that will occur in connection to changed primary and secondary productivity rates in the whole aquatorium of the north Adriatic. This could convey to serious disturbance and stressing conditions within and among fish species in their specific community and population structures. We can thus expect to observe some deviations of their species, genetic, community and ecosystem diversity indexes (EPA, 1989). For the moment it is definitely impossible to exhibit any rational scenario about a realistic evolution of the presumed changes of the fish stocks. Very little is known about qualitative and quantitative relationships within and among species in single communities. Very scarce is the knowledge about ecophysiological characteristics and relationships. Thus we do not know what are the limits of tolerance regarding temperature, salinity, light, nutrients and food supply within which any single species and the entire community can reproduce, growth and survive.

At present, over-fishing and trends to further increase the fishing efforts with the employment of the most sophisticated tools and fishing techniques are the most serious problems for the protection of the biological potential of fish stocks in all Adriatic. Actually, "small blue fish" are not yet endangered, but serious over-fishing trends are already endangering the biological integrity of demersal-bottom fish communities, with particular concern on the high quality "white - rocky bottom fish". Pollution in the Cres-Lošinj area is not of serious concern, and this problem should be analyzed in the frame of the conditions in the entire north Adriatic aquatorium.

Suggestion for action to avoid, mitigate and adapt to predicted effects

On the basis of present knowledge it is not possible to foresee any relevant evolution and suggest any pertinent action.

Suggestion for follow-up

Proper monitoring and fishery inspection should be established to control and avoid over-fishing and check other possible changes of the fish stock structure. Particular attention should be paid to avoid or decrease any probable pollution, to prevent destruction of habitats, their degradation and fragmentation. These impacts affect community and ecosystem diversity, distress biological diversity and reduce the pool of genetic diversity of any single species. Thus the spontaneous self-sustaining and auto-defence mechanisms of all elements of the communities and populations should be reduced. Population structure and dynamics of the main leading species and their migratory patterns should be particularly observed.

2.6.3 Mariculture

Past trends and present situation

Mariculture facilities are usually situated along the coastline, but with preference inside of sheltered bays, where the connection and the approach from the land based installations is facilitated. The coast line of the island of Cres is about 470 km long, of Lošinj is nearly 110 km and the average indented coast line index is about 1.60 and 1.65 respectively. Thus most of the rocky shore is rather steep and facing the open sea, with exposition to strong and hasty winds from the I and IV quadrants, which is not suitable for the installation of mariculture facilities. Along the coast we find only a few calm bays, but most of these inlets are traditionally occupied with urban, shipyard and harbor settlements that are in contrast with the requirements for the development of mariculture activities.

At the turn of the century some shellfish cultures were introduced in the Cres-Lošinj area. The most favorable location for the production of oysters was initiated in the very calm and shallow bay of Piskel in the inner south part of the bay of Cres, where a modest fresh water spring supports favorable conditions for oyster cultivation. The production reached about 100.000 oysters annually. Other facilities for oyster cultivation were installed in the inner part of the Lošinj bay, east of Osor, in two locations in the north-west part of the Mali Lošinj bay and in the Rovenska bay nearby Veli Lošinj. The fate of all mentioned projects was very similar, and already before the end of the first decade of this century all the activities were suspended and not even after the first world war were continued. The breakdown was without no doubt related to economic failure: high cost of production and to low market price of products.

Other calm and flat bays were traditionally used as protected fish ponds, where at determined time fishermen were used to trap adult fish for the market or to collect juvenile fish for fish farming.

In the meanwhile, nearby the urban centers of Cres and Lošinj, shipyards and harbors activities started to expand, and substantially great segments of the gravitating aquatoria were occupied. During the last decades the same trends continued, but with higher intensity when the touristic activities started to became one of the most promising economic activity in the region. Thus, most of the remaining bays were definitely excluded as potential locations for aquaculture ventures.

Presently, in the Cres-Lošinj region no aquaculture is practiced, although in the near future this activity is envisaged. According to middle and long term physical planning, several bays were evidenced: the lowest-south part of the bay of Valun, the bay Ustrinska, some segments of the north-east coast of the bay of Lošinj and, because of its pertinent hydrophysical characteristics, special attention was recommended to check the possibility to reestablish mariculture activity in the north-east part of the Mali Lošinj bay, particularly after the release of this part of the aquatorium from military activities. However, the most suitable bay of Piskel was definitely excluded from any mariculture planning, because recently a touristic "marina" was established in the inner part of the bay.

According to present trends and positive experience in Adriatic and north Mediterranean mariculture, one can expect that initially domestic species will be introduced. In general it is supposed that fish farming in floating cages should be preferred. Sea bass (*Dicentrarchus labrax* L.) and gilthead bream (*Sparus auratus* L.) should represent the priority fish species, while oysters (*Ostrea edulis* L.) and mediterranean mussel (*Mytilus galloprovincialis* Lam.) will appear as accompanying shellfish production in polyculture systems.

Expected effects, and most vulnerable systems and activities

Anticipated climate changes, primarily related to the increased sea level, to the estimated temperature rise and consequently to modest alterations of salinity, hydrodynamics and trophic activity will not significantly affect the water quality characteristics, optimal for mariculture.

The sea water level increase should be considered as essentially insignificant for mariculture. Neither the increased water body volume nor the slight surface extension in the potential bays will create any critical impediment for the mooring of fish farming cages, oyster and mussel parks and other floating systems on the sea as well as the construction of land based facilities along the appropriate shore line.

The mentioned domestic fish and bivalve species appropriate for mariculture production are all eurytherm and euryhaline, and thus easily adaptable to predicted changes of the physical and chemical environmental conditions. If the anticipated mean increase of about 2 °C is an estimate concerning the whole year heat budget increase, we can in general suppose that it will promote their growth rate. On the other side, the corresponding increase of salinity could recede the growth rate because of the increased consumption of metabolic energy required to compensate the altered osmo-ionic equilibrium. Temperature increase will particularly in summer slightly decrease the saturation level of oxygen which basically could also induce a complementary loss of metabolic energy consumption. However all mentioned variations of the environmental factors, are presumed to fit within the optimal tolerance limits which are required for an equilibrated and economically profitable growth rate of the species of concern. According to various authors (reviewed by Barnabè 1980) the optimal limits of the environmental factors for the sea bass lay in the range between 10-25 °C, 10-30 salinity and 4.5-8.0 mg O_2 ml^{-1}. However frequently sea bass was found to migrate and reside in extremely colder (5-6 °C), brackish (3.9 salinity in laboratory or 7.0 in natural estuary conditions) or in highly saline conditions (90 sal). Very similar is the behavior od gilthead bream. Like sea bass it lives along the coast but frequently enter into lagoons and estuaries (in the range of 20-45 salinity) but is more sensitive to lower temperature levels (Ghittino 1978). The optimal salinity range for oysters lays between 28-32 sal. and 15-25 °C. Mussels are cultivated in coastal zones where the salinity range is between 30-36 and temperature 10-25 °C.

While fish farming is completely based on supply of natural row foods or industrial foodstuffs, the growth of oysters and mussels depends on the available plankton organisms and organic suspended matter in the environment. Thus any change of trophic relationships, particularly the presumable changes in planktonic population structure could alter their feeding patterns which could influence the growth rate in the positive or negative sense as well. At the same time, in case of dystrophic conditions and particularly to the probable evolution of "monoculture" phytoplankton blooms one can expect the appearing of highly poisonous phytotoxins produced by some dynophlagelates (?), which are accumulated by filter feeding bivalves and thus represent a serious hazard for humans.

Other factors that can influence growth, production rate and costs are related to the probable appearance and epidemic development of bacterial or viral diseases and other pestilence, which are significantly promoted in higher temperature conditions.

Very little is known about the influence of environmental factors on the appearance and infestation of fish and molluscs with parasites.

Suggestion for action to avoid or mitigate the effects and to adapt to the changes

Quotation of potential sites for the settlement of marine farms should be based on relevant and classified data about the physical hydrographic and bionomics properties of the environment. At the same way the anticipated climatic and environmental changes should be taken into account for the selection of species and relative farming technologies.

To avoid dystrophic condition monitoring of water quality and appropriated sewerage systems should be promoted and established.

To prevent potential pestilences, parasites and eventual phytotoxin infestation higher hygienic standards and specialized check-up should be required.

Suggestions to follow-up

Mariculture is a relatively novel economic category, that in future is going to develop very intensively. It is thus expected that new technologies and other species will be introduced. It will be of great interest to explore about the introduction of domestic and exotic thermophylic species, like shrimps, abalones and presumably sea-weeds. In the case of exotic species special attention should be devoted to the possible undesirable and in some cases definitely unacceptable consequences regarding their compatibility with the domestic environment.

2.6.4 Sylviculture

Past trends and the present situation

The forest cover of the Cres-Losinj district belongs to two climatic zones. The northern part of the island of Cres,northward from the Sv. Blaz - Merag line, belongs to the sub-Mediterranean zone of deciduous forests. These are pubescent oak and oriental horn beam forests (*Querco-Carpinetum orientalis*) in the altitude zone from sea level to 250 m above sea level, and pubescent oak and hop horn beam forests (*Ostyro-Quercetum pubescentis*) from 250 m above sea level to the highest peaks of Cres, Gracisce (622 m), Sis (638 m) and Kal (456 m). Within the pubescent oak and oriental horn beam forests, there are subassociations of pubescent oak and oriental horn beam with Turkey oak (*Querco-Carpinetum orientalis subas. cerretosum*) on terrains characterized by funnel-shaped holes in the limestone formation. Also, where there are deeper and cooler soils, there are azonal associations of sweet chestnut (*Querco-Castanetum* sub-mediteranneum Anic) north-west of the village of Beli.

The plateau on the slope around the Vransko Lake also belongs to the sub-Mediterranean climate. There used to be Turkey oak and virgilian oak forests (*Quercetum cerris virgilliana*) here. Today most of these forests have been cleared and may be found individually on relatively small areas or in stages of degradation. The highest peak of the Island of Losinj, Osorcica (588 m) is also in the sub-Mediterranean zone of pubescent oak and hop horn beam. In general, it may be said that the sub-Mediterranean zone covers approximately 30% of the total surface area of the Cres-Losinj district, while the remaining surface area is covered by Eu-Mediterranean evergreen oak forest, amounting to 70% according to the potential vegetation map.

In the Eu-Mediterranean zone of evergreen oak forests, forest associations are graduated according to minor climatic changes. The coolest forests are holm oak forests with hop horn beam (*Ostyro-Quercetum ilicis*). The forest on the eastern coast of the island of Cres from Predoscica to Meraga is exposed to strong gusts of the bora (north-eastern wind). This forest association is a rarity in the entire Adriatic area.

Warmer areas are covered by mixed holm oak and flowering ash forest associations (*Orno-Quercetum ilicis H-ic*). Apart from evergreen trees, there are also deciduous tree and shrub species in this forest. It is dominated my macchia as a stage in its degradation. This forest association covers most of the surface area of the district - the central and southern part of the island of Cres and the greatest part of the island of Losinj. Somewhat warmer areas are covered by kermes oak and flowering ash forests (*Orno-Cocciferetum*) west of the village of Cunski. These are a natural-scientific rarity. This is the northernmost location on which this forest is found in the Adriatic region (its range is located mostly south of Dubrovnik). The warmest association of pure holm forests (*Quercetum ilicis adriaprovinciale Trinajstic*) grows on the lower and sheltered parts of Losinj, in the immediate vicinity of the sea, exposed towards the south and south-west, from the Kuril Peninsula via Cikat to Ilovik, and on Unije and the island of Srakane. It is dominated by evergreen species. This kind of forest is typical of the southern Adriatic islands of Hvar, Korcula, Mljet and Peljesac. The Aleppo pine can also be found in this forest association. It was planted artificially here in 1886, when tourism began to develop in Cikat. Today the Aleppo pine is spreading naturally from these cultures. It has reached its optimum development here, with very fine elite trees, and has enhanced the landscape considerably.

There are also significant areas covered by black pine cultures planted on the plateau of the island of Cres around the Vransko Lake on Osorcica, as well as by road-sides and around settlements. These forests have primarily a protective function: to protect from wind and erosion. Since the black pine is outside its natural range here, the trees are of a rather poor quality and are frequently attacked by pests and disease.

Historically, from Greek and Roman times to the present day, the evergreen oak forest zone was the most suitable for human habitation (with regard to climate, the gentle slope of the terrain, and better quality soils), and for this reason the area covered by these forests was cleared for agriculture and cattle-raising. These agricultural areas were insufficient for the numerous population and so, after the vineyards withered away and died in the 19th century, there were large-scale migrations of the population across the ocean. The forest is now returning to the abandoned agricultural areas by natural succession, and, due to the development of tourism, pine cultures are being planted there. In the deciduous zone, the forests have retained the same surface areas as formerly, with slight changes, while around the Vransko Lake the forest was cleared for pastures.

Various types of rocky pastures have developed as the last stage of forest degradation: pastures of *Chrysopogon gryllus* and spurge with sedge (*Chrysopogon-Euphorbietum nieusis Caricetosum humilis*), pastures of Illyrian meadow fescue grass and bulbous June grass (*Festuco-Koelerietum splendentis H-ic*), and pastures of medicinal sage and feather-grass (*Stipo-Salvietum officinalis H-ic*) covering significant areas.

Cres and Losinj are wooded islands in the Adriatic region. The area covered by woodland amounts to 62% according to data collected by the Faculty of Forestry and Agriculture, Zagreb, and published in the Study on the Soil and Areas Suitable for Agriculture and Forestry on Cres and Losinj in 1988, while according to the data in the land register of 1978, woodland covers 42% of the surface area. The difference is due to the fact that new areas covered by macchia, as well as some of the pastures on which there is a large proportion of trees and shrubs, have been included in the category of woodlands. According to the land register of 1978, there were 8,027 ha of evergreen oak and macchia, which amounts to 15.6%, while according to the latest data the proportion of these forests is 17,805 ha or 56.5% of the total surface area of the district. The areas of pasture have dwindled from 17,856 ha, or 34.8%, and been replaced by new forests on 5,222 ha, or 10.2% of the total surface area of the district.

Of the total woodland areas, 43.9% are owned by the state, while 56.1% are privately owned. Tended forests which are being managed cover 5,992 ha (or 1/5). Programmes of management calculated to improve these forests have been made.

Non-woodland areas -		19,817 ha	(38.6%)
Agricultural areas		4,002 ha	(7.8%)
Reed-patches		154 ha	(0.3%)
Pastures		12,634 ha	(24.6%)
Thickets		3,027 ha	(5.9%)
Woodland areas	31,493 ha	(61.4%)	100%
Holm oak and macchia	17,805 ha	(34.7%)	56.5%
Pubescent oak, oriental horn beam and hop horn beam	5,798 ha	(11.3%)	18.4%
Sweet chestnut	154 ha	(0.3%)	0.5%
Turkey oak and virgilian oak	513 ha	(1.0%)	1.6%
Pine cultures	2,001 ha	(3.9%)	6.4%
Pastures which have become woodland	5,222 ha	(10.2%)	16.6%

The most wooded areas on the island of Cres are the areas of evergreen oak forest on Punta Kriza with 73% woodland, followed by the deciduous forest area of Tramontana with 67% woodland, and Cikat on Losinj with 62% woodland. The other areas are considerably less wooded.

The Programme of Forest Management for State-Owned Forests should improve these forests considerably, making use of new insights gained by the science of forestry. A study for the forests of the Tramontana forest management unit was made in 1988. The Study on the Soil and Areas Suitable for Agriculture and Forestry on Cres and Losinj was made in the same year, while a programme entitled A Model for the Tending and Regeneration of the Cikat Woodland Park was made for Cikat in 1990. Studies for the management of the other state-owned forests in the Vrana, Punta Kriza and Cikat areas are under way. All these forests are managed by the company Croatian forests, Buzet Forest Management, Cres Forestry.

There are no such programmes for privately owned forests (56.1%), which are managed in the traditional way. Firewood called "Mediterranean cut wood" is felled in the evergreen oak forests. Of these areas, 60% are covered by macchia, while only 40% are covered by coppice forests.

In the Tramontana deciduous forests, firewood was also cut by traditional methods, i.e. by topping the trunk at a height of 2 - 2.5 metres. Thus new branches would grow from the trunk, and when they reached the thickness required for firewood they were cut at the same height. By this method, firewood was produced from individual old trees for as long as several centuries. Due to constant cutting in the same place, fungi invaded the trunks, so that most of these old trees have completely rotten and hollow trunks.

The development of hunting tourism by importing fallow deer upset the traditional method of managing holm oak forests, since the young shoots sprouting up after the trees were cut were eaten by the deer. The development of hunting and the interests of forest management should be coordinated.

In the zone of pure holm oak forests there is a danger of extensive clearing of the forests in order to build hotels, and interests must be coordinated in this area also.

The expected effects and the most vulnerable systems and activities

- the expected climatic changes will have an effect on the composition of forests, and changes will take place in the holm oak forest zones. Deciduous trees will recede and evergreen elements will take their place. Mixed evergreen oak forests with flowering ash will thus undergo changes and a gradual transformation into pure evergreen oak forests. These forests will then be more vulnerable to forest fires;

- the existing line of demarcation between deciduous forests and evergreen oak forests will not change significantly, since deciduous forests are more exposed to cold winds (the bora NE and the tramontana N wind) during the winter months and grow at a higher altitude;

- in the deciduous forest zone, the greatest changes will take place in the sweet chestnut forests. The soil moisture is decreasing significantly due to warming, and this will speed up the withering away and dying of sweet chestnuts, weakened by disease (*Endothia parasitica*). Unless grafted seedlings resistant to this disease are planted, this species will probably become extinct by the year 2100;

- an increased danger of forest fires is expected;

- these climatic changes will have a negative effect on the unstable forest ecosystems (degraded forest areas and pine cultures) which play a pioneering role in this region and make it possible for natural autochthonous forests to develop;

- there will also be negative effects on highly degraded rocky pastures, where there is a danger of extensive soil erosion;

- the occurrence of diseases and pests (insects) in the forests is expected to increase:

- bare patches caused by gipsy moths (*Lymantria dispar*) and brown-tailed moths (*Euproctis chrysorrhoea*) are expected to occur on deciduous trees, and bare patches caused by pine processionary moths (*Cnethocampa pityocampa*) and attacks of sawflies *Diprion pini* are expected to occur on black and Aleppo pines;

- a heavy attack of buprestids (*Bupestris cupressi*) is expected on cypresses and cedars;

- an attack of *Caraebus fasciatus* is expected on evergreen oak trees;

<u>Suggestions for action to be taken to avoid or mitigate the expected negative effects</u>

- stable forest ecosystems should be established. Degraded forest and macchia should be transformed into coppice forest, coppice with standards (with trees growing from seeds and from stocks), and high forest (with trees growing from seeds). In the case of deciduous forests, the forest should also be transformed into higher forms. This kind of forest is more stable with regard to fires and diseases and is far more useful generally, as well as representing a firm environmental foothold for man (agriculture, tourism, hunting tourism, greater timber and firewood production). The forest thus has an optimum environmental and general social function (the environmental benefits of the forest);

- elements of autochthonous forest vegetation should be introduced into pine cultures. Thus evergreen oak should be introduced into Aleppo pine forests, while deciduous trees (primarily pubescent oak, bitter oak, oriental and hop horn beam) should be introduced into black pine cultures. These forests will then be more stable and resistant to fire and disease, and their protective role in the environment will thus be enhanced;

- preventive fire protection should be increased (the construction of straight clearings for purposes of fire prevention, regular cleaning and tending of forests, an organized fire fighting service and regular observation);

- all terrain with a slope of more than 30% on which there are no forests, as well as areas which are more than 50% rocky, should be afforested. This will prevent soil erosion (water and eolian erosion). Afforestation should be started by planting Aleppo pines with evergreen oaks, or black pines with deciduous species (2,000 pine seedlings/ha along with the planting of acorns or other deciduous species).

Suggestions for action to be taken to adjust to the changes

It is suggested that cultivation measures be taken to bring the forests into their optimal state, in order that they should be stable and vital and at the same time provide the maximum benefits. Certain cultivation measures have been planned in the Study on the Soil and Areas Suitable for Agriculture and Forestry on the basis of recent scientific insights. According to this plan, woodland areas should be increased by 66% by the year 2000, and the wood mass would be doubled. This is easier to carry out on forest areas owned by the state. In privately owned forests, which make up 56.1% of the woodland areas, the plan will be implemented much more slowly and traditional methods of forest management will have to be changed. These processes will be slow in privately owned forests because they cover small areas split up among numerous owners, and the changes will depend exclusively on the interests of the forest owners.

Suggestions which should be followed

The forests now growing on the islands of Cres and Losinj have been handed down to us by former generations and reflect certain economic and political trends. Forestry as a branch of industry does not produce the desired results immediately, and only one fire can destroy the effort of several centuries. Today tourists enjoy the beautiful old pine forests of the Cikat woodland park which the industrious citizens of Mali Losinj planted a hundred years ago. If the recommendations of forestry experts are followed and the proper direction of economic development is taken, if all the measures suggested above are carried out and good regional planning policies are adopted, we are certain that these forests will develop, and climatic changes should not have negative effects on the forests.

CRES-LOŠINJ

2.6.4 SYLVICULTURE

Designed by Miroslav Rukavina, 1992.

1. Pure Adriatic holm-oak forest and shrubs (Quercum ilicis aalne prasinatale Trinajstic)

2. Holm-oak forest and shrubs with flowering ash (Orno - Quercetum ilicis H-ić)

3. Holm-oak forest and shrubs with hop hornbeam (Ostrya - Quercetum ilicis Trinajstić)

4. Pubescent oak forest with oriental hornbeam (Querco - Carpinetum orientalis H-ić)

5. Pubescent-oak forest with hop hornbeam (Ostrya - Quercetum pubescentis Ht. et H-ić.

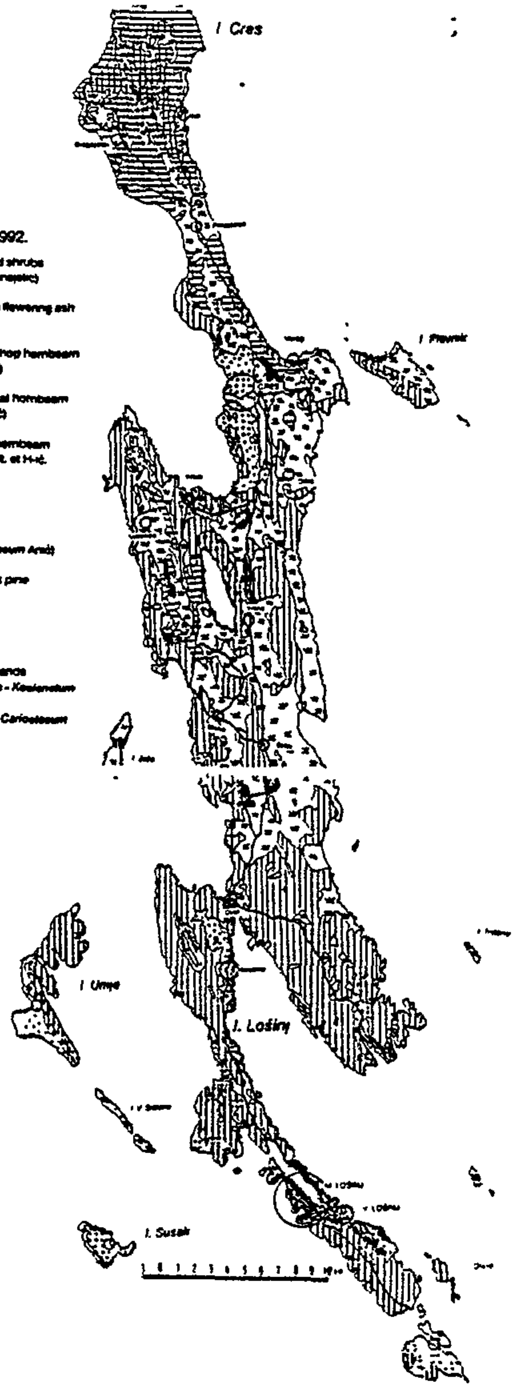
6. Turkey and virgilian oak forest (Quercetum cerris- virgilianae)

7. Oak forest with sweet chestnut (Querco - Castaneum submediterraneum Anić)

8. Pine cultures - Aleppo pine, black pine

10. Agricultural areas

11. Mediterranean xerophile grasslands (Stipa - Salvietum officinalis, Festuca - Koelerietum splendentis H-ić; Chrysopogon - Eulorhetum nausis Cariostaeum humile)



2.7 Energy and Industry

Past trends and present situation

There are not many industries on the archipelago Cres-Losinj. Industries include three shipyards, a fish canning factory, an olive oil factory, a textile factory and a slaughterhouse. Two marinas and two petrol stations in the coastal area could be added as well.

The textile factory "ADRIATRIKO" with 53 employees which produces ready made textile products and the seasonal olive oil factory are situated in the centre of the town of Cres.

The fish canning factory "PLAVICA" with 54 permanent and 10 temporary employees is located in the coastal area of the town of Cres. The plants of the factory are situated on 1,2 to 5,4 meters above sea level, and the sewerage pipe is on 0,12 m above sea level.

The repair shipyard Cres with 132 employees is located on 0,24 to 2,54 meters above sea level. There is a floating dock of 1000 tonnes, and the height of the operating berth is +1,40 meter.

Marina Cres with around 500 berths is located in the bay of Cres.

The petrol station in Cres is located near the coastal area on 2,54 meters above sea level.

The shipyard Mali Losinj for construction of iron ships up to 1500 dwt, wooden boats up to 700 dwt and repairing of ships up to 5000 dwt has 200 employees. The operating berth is on 2,0 meters above sea level.

The shipyard Nerezine is a part of the shipyard Mali Losinj, with 16 employees for construction of wooden boats up to 6 meters length.

Marina Mali Losinj with 33 employees and the petrol station is located in the coastal area of Mali Losinj.

Electrical power, supplied from mainland from the electric transformer 110 /35 kV Krk through two conductors, underwater and underground cables 35 kV to Cres and Losinj is the main source of the energy on the archipelago. The length of the underwater cables is around 17 km. The present requirements of the archipelago are 15 MW; the requirements for the year 2015 are estimated as 75 MW. The electrical power network consists of electric transformers < (some situated in the coastal areas), electrical network 110 kV, 35 kV and 10 (20 kV).

There is no gas line on the archipelago, because gas sources and the main gas lines are far away from the whole Rijeka region.Only certain quantities of LPG (liquefied petroleum gas) are used mostly in housing and has a low influence in the total energy consumption of the archipelago.

For preparing of hot water in private houses and in some touristic places as well as for the lighthouses, solar energy is used.

Expected impacts of the climate change on industry and energy

Temperature elevation is not expected to have a significant effect on the operation of the present industries.

The total annual requirement for electric energy will probably remain the same, but with some decrease in winter (less heating) and increase in summer (a more intensive use of air-conditioners).

Sea level changes will affect the fish canning factory, the shipyards, the marinas, the petrol stations and the electric transformer stations situated in the coastal areas.

Suggestions for actions

The fish canning factory would have to be either protected by a seawall, relocated,or closed.

The shipyards and marinas will have to adopt their facilities by rising their operational working surfaces.

It is not necessary to find out the way how to solve the problem with petrol stations because they will be relocated according to the Physical plan of the Commune of Cres-Losinj.

The electric transformers will have to be either moved to a more appropriate location or raised.

It would be necessary to elaborate the possibility of using the solar energy on the archipelago Cres-Losinj, because there are even now more than 200 sunny days and an increase of sunny days could be expected due to the predicted climate change scenario .

As tourism is the main activity of the archipelago of Cres-Losinj, with the highest requirements for energy in summer solar energy should be used. There are already many tourist places on the Adriatic coast where the use of solar energy alone, or combined with other systems is already applied.

The recent Report of Commission of the European Communities to the United Nations Conference on Environment and Development, Rio de Janeiro 1992.,predicts in the countries of ECE, the production of energy from the renewable resources by the year 2010 not to exceed 8 per cent.

2.8 **Tourism**

2.8.1 Past Trends and Present Situation

The area of Cres-Losinj archipelago is distinguished by favourable natural conditions and attractions for the development of tourism, as well as by long and stirring history expressed in the rich cultural and architectural heritage, which is not appropriately evaluated although well cherished by local population. In the present tourist supply the 100-years-old tourist tradition of the archipelago is inadequately promoted, as well as the image of Mali Losinj being a European medical treatment centre for a long period of time.

Long tourist tradition of Mali Losinj and tourist development, being mostly cyclical up to now, have contributed to the commune to become an important tourist area in the Republic of Croatia.

According to the statistic data for 1987 (the most successful tourist season in Croatia up to now) the share of the commune in the bearing capacities of Croatia was 4,2 per cent, while the share in Rijeka macroregion was 8,2 per cent. The bearing capacities are spread over all kinds of accommodation facilities and dispersed, although unequally, over more than 15 settlements and tourist localities of the archipelago.

So far, the tourist development of the Cres-Losinj archipelago was concentrated in a few tourist places and more important tourist localities (mostly in the close vicinity of tourist places) supplied by infrastructure of good quality. The tourist facilities haven't threatened natural and anthropogenic sustainability of islands' area.

The most unfavourable ratio of number of inhabitants and existing accommodation facilities is recorded in the settlements of Martinscica, Punta Kriza and Nerezine. However, it hasn't reached the permissible limit according to the available coastal area, as it is already the case on some other Mediterranean islands. There is over 75 per cent of accommodation facilities of the tourist supply in the surroundings of four main tourist places, i.e. Mali Losinj, Nerezine, Cres and Veli Losinj.

Structure of bearing capacities per tourist places of the commune of Cres-Losinj in 1987 and categories (A, B, C, D) of the tourist places from 1991

Tourist place	Category of the tourist place	Total bearing capacity (basic and complementary),beds
BELI	B	457
CRES	A	5.726
CUNSKI-ARTATORE	B	956
ILOVIK	C	340
MALI LOSINJ	A	17.016
VELI LOSINJ	A	3.943
MARTINSCICA-MIHOLASCICA-STIVAN	C	5.077
NEREZINE-SV. JAKOV	A	5.953
OSOR-LOPARI	A	2.514
PUNTA KRIZA	A	2.421
SUSAK	C	354
UNIJE	C	566
VALUN	A	580
Total of the commune		45.903 beds

Although the length of shoreline suitable for bathing is considerable, i.e. 1/4 or 125 km out of the total length of 506 km can be easily accessed, in the peak season a great pressure on the physical capacity of these localities is exerted due to the relatively low number of natural sandy or man-made beaches.

In the past tourist activities, the periodically uninhabited or abandoned houses in the smaller tourist settlements were not used enough. Last census of 1991 registered about 350 uninhabited and 250 abandoned buildings (almost 20 % of the total number of residential buildings) which could and should have had a more adequate tourist treatment (through specific diverse forms of tourist supply) initiated through more qualitative social intervention and organization, being protected from further dilapidation.

The total decrease in the number of inhabitants of smaller settlements leads to the decrease of the manpower what creates the constrains for the future tourist development. Therefore, without new mechanical inflow of qualified population, the future tourist development won't be possible in those places.

The existing structure of the accommodation facilities supply is unfavourable when compared with the market demand, possible market supply of the archipelago, available natural resources and the neighbouring tourist areas.

Structure of bearing capacity in 1987 (the tourist season with maximal number of tourists and overnights until now)

Accommodation type	Commune of Cres-Losinj 1966	1986	Rijeka macroregion 1986
1. Hotels, apartments and boarding houses	10,5 %	11,8 %	21,8 %
2. Private accommodation, holiday homes (for workers and others)	62,0 %	47,0 %	36,0 %
3. Camps	27,5 %	41,2 %	42,2 %
Total	100 %	100 %	100 %

The share of supply of the basic accommodation facilities (hotels, apartments, boarding houses) is only 11,8 % in the total bearing capacity.

Among complementary accommodation facilities dominate camps (41,2 %), private accommodation (27,6 5) and holiday homes for workers and others (19,4 %). With regard to the relative share of holiday homes within the whole bearing capacity structure, the commune of Cres-Losinj is one of the leading in the macroregion of Rijeka and even in Croatia. Although the share of these capacities is decreasing for the period 1966 - 1987 it still isn't optimal. During the peak season these accommodation facilities (especially camps) exert great pressure on the communal and other infrastructure systems/networks, thus approaching to their limiting scale.

Since almost half of the hotels is fitted out for all-year-round business activity (central heating, although not enough complementary services), a different dynamic should be introduced in the present running of business.

Use of accommodation facilities in 1987 with regard to the facility type, in days/year

Facility type	Commune of Cres-Losinj	Macroregion of Rijeka
1. Hotels	170,2 days/year	181,2 days/year
2. Holiday homes	71,0	71,0
3. Camps	67,7	70,8
4. Private accommodation	61,7	69,6

In the structure of market demand trends, the demand for accommodation in fixed constructions (hotels, apartments, boarding houses and private accommodation) is prevailing, while among different tourist forms there is a trend toward: health tourism, nautical tourism, sport tourism, club tourism, excursion tourism, cruise, nudism and naturalism, hobby trips, prolonged weekend and other diverse forms of tourism.

Island tourism, as a whole, is also in trend, and its guests are mainly homogeneous guests. The frequency of their travel abroad is above average. A forth of them travel several times a year on holiday, so they are more experienced and demanded as users. Their social and educational status are higher than average and they belong to the younger age group (20 - 40 years).

In the peak tourist season, about 2000 working people (permanent and seasonal) took part in this economic activity in 1987, which means that about 50 % of the total island population lived directly or indirectly of tourism.

2.8.2 Expected Effects and Most Vulnerable Systems and Activities

Tourism is economic and human activity which experienced one of the most dynamic developments and diverse transformations in the terms of contents, in the past hundred years. The existing tourism is strongly connected to the civilization demands and socio-economic relations of people at the end of the 20th century. According to our opinion, it appears also as the answer of modern urban population to ecological disaster caused by technological revolution. Today it is among the activities with the most dynamic development rate. Besides all mentioned above, the kind and extent of future tourist flows are uncertain.In another way, it is hardly to believe that these accelerated trends will continue over the next century, too. It simply seems impossible for hundreds and millions of people to be physically moved from one place to another which are supposed to be more attractive in ecological, cultural and ambient sense. Tourism will, for sure, just as entire human civilization, go through transformations during the next century.It is almost impossible to predict at present which values will future tourism prefer and what kind of physical extent will have. Yet, it could be expected that natural ambient attractions will be appreciated in the technological world of tomorrow. The island will probably, as the oasis within the sea of urban world, have an exclusive position.

Therefore, it could be foreseen that climate changes with the consequences threatening to immediate coastal areas (beaches and other natural bathing places, areas of historical value within the coastal settlements) and with the changes of global climate islands features, will cause an essential influence to the tourist activity in the future.

The climate change impacts will reflect in the positive way to the prolonged tourist season and tourist activities. Since it is probably to expect that islands area will become even more suitable for development of diverse forms of tourism, a milder climate and longer tourist season will contribute to the further qualitative development.

On the other hand, sea level rise could,because of flooding or overflowing of numerous beaches and parts of coastal settlements, have the negative impact to particular forms of tourist supply/demand.Higher average air temperatures could cause serious consequences in agricultural production, which is to be a part of specific autochthon tourist supply on the island area. The coastal forests under intensive use are expected to be more vulnerable to fires, and the water-supply system from the Vrana Lake,too.

2.8.3 Suggestions for Action to Avoid or Mitigate the Effects

The climate change and sea level rise could be of considerable importance for the tourist development, being the activity strongly dependent on natural environment, economic activities in the whole and the way of people's life,no matter of relatively long period of time for exposing the manifestations of those changes (by 2050 or 2100 AD). It is necessary to be aware of their possible impact already now, not with the aim to call for common panic, but to determine specific policy and measures which could help to avoid or mitigate the negative consequences.

Tourist area could be divided into immediate coastal area and wider area. The first group would consist of bearing capacity area with facilities of complementary services and beaches/bathing places. These places are not, at present, under the direct threat since almost all of the buildings are out of immediate coastline. Bathing-places as well as sport and recreational areas have such natural/relief features that they won't be endangered by future changed climate conditions.

The new construction of all the tourist facilities is oriented to the invulnerable areas in the physical plans. All the other measures are in accordance with those mentioned in chapters 2.11.3. and 2.11.4. since a great part of tourist capacities is situated within the cities and settlements.

2.8.4 Suggestions for Action to Adapt to the Changes

The future tourist supply development of the commune of Cres-Losinj should follow the orientation of qualitative tourism, providing and respecting maximal landscape protection with the aim of recreational and health function.It should also provide protection of authentic and ethnographic living elements as well as cherishing of landscape at the level appropriate to the kind and quality of tourist supply of settlements, commune and region. The island tourist supply is suggested to take a course of unique tourist supply for the whole archipelago's area,with more balanced development. It is also suggested to determine such a tourist capacity scale which will consider local people as the limiting development factor; development of individual living quality of local people; orientation to the accommodation facilities of higher quality; revitalization of smaller islands through development of diverse tourist forms and programmes; revival of historic valuable sites and enrichment of the tourist supply as a whole.

Tourist capacity, according to the optimal development scenario by 2015, would be distributed to three development and business areas:

Development area	Beds	%
1. Cres	12.920	23,5
2. Osor	19.910	36,3
3. Losinj	22.050	40,2
Total	54.780	100%

Nautical tourism centres, marinas and other facilities could accept (by 2015) up to 2100 boats and 8500 tourists (4 beds/boat). Nautical tourism ports are:Cres, Mali and Veli Losinj, cove Ul, Baldarin, Ilovik, Nerezine, Susak, Martinscica, Artatore, Unije and Lopari. In the physical plan is established the physical distribution according to the kind and category of nautical tourism ports. In other tourist places of the Cres-Losinj commune, the berths for local population's boats and daily seasonal boats should be provided.

For the implementation of optimal scenario of tourist bearing capacity development until 2015, 4000 working people will have to be engaged (200 of them for nautical tourism). Since so far about 1900 working people were employed during the peak tourist season, that means that about 2520 new workers are needed, i.e. 1465 permanent workers and 1065 seasonal workers. The increase of new supply, offering higher level services will call for special educational prepare and particular skills which should have their expression through concrete development programme.

The projecting bearing capacities will develop gradually, in accordance with financial possibilities of tourist supply subjects in commune and the society as a whole. In order to carry out the rational development policy, the following orientations are suggested: parallel development of tourist supply of Cres and Losinj so as to be able to realize projecting substitution of bearing capacities and to implement the unique market supply; development has to be directed primarily into the tourist zones and localities already equipped by infrastructure and detailed programmes; within the frame of existing programmes the priority should be given to those, promising better export and income results and the ones helping to the image of the whole archipelago's supply.

2.8.5 Suggestions for Follow-Up

Since the prevailing part of the tourist bearing capacities are in the cities/settlements or in the tourist zones in their immediate vicinity, numerous research themes mentioned in chapters 2.11. and 2.9. are the same as for this one.

No significant impacts caused by climate changes are to be expected to this economic activity,due to natural characteristics of coastal zones of the Cres-Losinj commune (relatively steep coast, rocky beaches, a few sandy beaches)..That's why it is assumed that the envisaged researches for chapter 2.11. would almost completely satisfy this chapter, too.

2.9 Transport and Services

2.9.1 Past trends and present situation

In the commune of Cres-Losinj there was 198.5 km of roads in 1988, of which 83 km of regional roads and 115.5 km of local roads.Parameters of transportation infrastructure development are visible from the ratio of road network and the surface area of the commune (38.7

km/100 km^2), and the ratio of road network and the number of inhabitants in the commune (191.6 km/10 000 inhabitants).*Comparing these facts with the same-time average of macroregion of* Rijeka (52.7 and 82.3) and the whole territory of Republic of Croatia, relatively low network density in the commune of Cres-Losinj is obvious, but also relatively more suitable network density in the relation with number of inhabitants.

Considering the state of pavements in the commune, 1695 km of roads are registered as roads with modern pavements, with the rate of modernization of 85.4% what exceeds the average for macroregion of Rijeka and the Republic as a whole.

Outline of road network for the commune of Cres- Losinj

ROAD TYPE	LENGTH (km)	KIND OF PAVEMENT			
		ASPHALT		BROKEN STONE	
		km	%	km	%
REGIONAL	83	83	100	-	-
LOCAL	115.5	86.5	75	29	25
TOTAL	198.5	169.5	85.4	29	14.6

Relatively good road traffic connection of the commune of Cres-Losinj with other centres in Croatia, as well as with other transportation routes represents one of the most important factors of past and future economic and social development. Today's basic road connection is regional road R - 2760 leading towards ferry-terminal of Porozine/Merag - Cres - Osor - Mali Losinj - Veli Losinj.

Transportation and technical elements of this road do not satisfy the transportation needs of the area today, and during the summer months a very low level of transport services is recorded.Local roads as capillary system of the network take over the role of connection among all the settlements.In the area of commune there are 115.5 km of local roads with 86.5 km of modern pavements.

General judgement regarding road traffic routes is their bad construction condition and low level of technical standard and safety. Technical elements, such as horizontal and vertical road serve, slopes, level reference line pavement width and bearing capacity, of most of the roads do not answer to the standards.Average annual daily traffic on the regional road R - 2760 (Porozine/Merag-Cres-Mali Losinj) was about 2 000 vehicles, and average summer daily traffic was about 2 800 vehicles in 1987.

The rate of motorization was 7.7 inh./1 passenger vehicle in 1987, while it was 4.3 inh./1 motor vehicle, what is considerably above the average of the Republic. The increase in traffic accidents, in accordance with increase in the number of cars, is caused primarily by inadequate road construction on the islands of Cres and Losinj. Regional road is built up with numerous curves and without enough technical elements of equipment.For the physical organization of the communal area the local bus traffic is the most important, since the inhabitants of small settlements use it every day for going to work, shopping, school etc.

Transportation connections between the Cres-Losinj commune and wider area, as well as with road traffic system of the Republic is mainly determined by ferry-lines (Porozine-Brestova towards mainland-Istria and Merag-Valbiska towards island of Krk).*The transportation connections* are also oriented to the main road towards mainland, and regional road (R - 2760) as the capital transportation road on island of Cres and Losinj.

It is estimated that on this regional level of connection, traffic abilities are in accordance with traffic demands, so it doesn't make any significant constraint for further social and economic communal development. This estimate is mainly based on number of present-day ferry-boats and on the physical and maritime characteristics of ferry terminals Porozine/Brestova and Merag/Valbiska.

Maritime system enables passenger transport on the regional routes (between the cities).Ship lines in 1987 were established on the following routes:Mali Losinj - Susak - Unije - Martinscica - Cres - Rijeka (about 35 000 passengers a year); Mali Losinj - Ilovik - Zadar; and local line Mali Losinj - Vele Srakane - Unije - Ilovik - Susak - Mali Losinj (about 40 000 passengers a year). Ports having the function of public passenger transport are:Cres, Martinscica, Vele Srakane, Mali Losinj, Susak, Unije and Ilovik.

Tertiary airport is built up and it is in transport function on the territory of commune of Cres- Losinj.It is situated southwest of settlement of cunski. The distance from Mali Losinj is about 8 km air line, that is 10.5 km by road.Airport is located on the plain place about 40 - 50 m above sea level.

Today the airport is in the 1B category (according to ICAO) with the length of runway of 900 m (900 x 23 m runway and 80 x 40 m platform). The airport of Losinj, as the commercial international airport serves for domestic and international passenger trips by both private or smaller company airplanes. The annual transportation is about 300 airplanes a year with about 4 500 passengers, 900 flights a year for local demands, in the total about 2 800 taking off and landings a year.

2.9.2 Expected Effects and Most Vulnerable Systems and Activities

There will be two essential ways of manifestation of climatic change impacts to the transportation system.The sea level rise will cause more significant impacts,both the static and long-lasting and the one of dynamic and temporary character.

Static and permanent impact which is expected to manifest through mean sea level rise will require engineering adaptation in transport facilities appearing to be vulnerable.Dynamic and temporary impact which will be manifested through flooding of particular areas and facilities in the extreme meteorological conditions (waves, winds, high tide, additional sea level rise induced by atmospheric pressures etc.)

Both of these impacts will reflect mostly the maritime transportation facilities in the limited degree. All kind of ports are likely to be vulnerable:ferry terminals, passenger and cargo ports and other smaller ports in the coastal settlements.Raising of the level reference lines of coastal port facilities will be unavoidable necessity, maybe easy to solve.It is considered that more important difficulties will be the necessary protection of port aquatories from extreme dynamic sea attacks,i.e. upgrading breakwaters since higher waves are to be expected,stronger winds and more dynamic flux of water masses in the protected harbour areas.Since the existing harbours (especially ferry-terminals) are open to some wave directions (then they cannot operate), it is likely to expect that these periods will become longer.More intensified extremes of general meteorological events will probably deteriorate general conditions for the maritime transport.

The generally changed climatic conditions will affect road transport in two essential ways. Some low-lying parts of road network are expected to be permanently flooded and some of them temporarily,what will require reconstruction or relocation of these sections to higher level reference lines. The second essential impact will manifest through changed intensity of extreme precipitation, thus causing difficulties in the road transport (storms with flooding of roads, erosions, dirtiness of hydrotechnical facilities etc.)

It is not likely to expect that climatic change would affect air transport.The existing airport on the island of Losinj has general climatic conditions among the most favourable ones in Europe.It is possible that meteorologic conditions will cause the problems caused by winds or precipitation over more days than now, but it is not expected to experience any essential influence to air transport operation.

2.9.3 Suggestions for Action to Avoid or Mitigate the Effects

It could be generally accepted the fact that majority of threatened transport facilities are in the coastal cities of the commune of Cres-Losinj. Therefore, the way of avoiding or mitigating the consequences of climatic changes in the coastal cities and settlements, will be also applied to the vulnerable transport facilities. Because of the limited Physical possibilities (especially in the historical sites) reconstructions or adaptations of coastal port facilities will probably be carried out by raising up in the existing areas of ports' aquatory.

Directions and measures for transport system will therefore be ,a great deal, in accordance with those of settlement pattern.

2.9.4 Suggestions for Action to Adapt to the Changes

For the estimation of the future motorization rate of commune of Cres-Losinj the present trends were considered, as well as the existing state.

It is expected that the rate of motorization will be 300 cars/1 000 inhabitants (1:3,3) by 2000 ad. The road/maritime transport is estimated mainly on the basis of planned tourist beds number. According to that, the communal daily transport of 3270 - 3640 routes/day for each ferry-line direction is expected. Analyzing the state of road transport system it is noticed a considerable discordance between transportation demands and transportation supply of the system. The significant correction in direction of existing regional road in the protected area of the Vrana Lake is planned. Here it is also thought of main road, particularly the planned by-pass road of the Cres town (correction of the route) and of Nerezine. On the other parts of this main road the reconstruction and modernization is generally needed.

It is extremely important to take into account the way of solution for critical points with limited capacity.It is especially in connection with lift bridges in Osor and Priviaka (Mali Losinj), which need to be modernized.

In order to achieve longitudinal and transversal connection among the island of Cres and Losinj and mainland, as well as with adjoining islands (Pag ,Rab) it is a long-term suggestion for establishing the maritime route on location of Kovcanje where the conditions for navigational channel exist.In order to enable the approach to the southern part of the island of Losinj and to provide the possibilities of landing for quick ferry-lines Pula - Losinj - Zadar and ship lines with the island of Ilovik, the lengthening of road route R - 2760 'till the southern cape of the Losinj island is planned.

Maritime transport exists as a contemporary system to the road transport at the regional level and it is the mean of public passenger transport between the islands.Further improvements in the organization of local maritime transport to the small islands of Ilovik, Susak and Unije are to be introduced.It is for certain , that change for the better are expected at regional level,too, and mainly in the terms of transport means characteristics.

More qualitative inclusion of the commune into the Adriatic transport system alongside the coast is foreseen by that plan.

Main objectives and directions of rational transport system connection among commune of Cres-Losinj and Republican and International routes, are construction and development of main roads and regional road routes or improvements of local development axes so as to enable daily migration of the population ; orientation to the public traffic; maximal safety; economic efficiency and functionalism of transport system; diminishing of negative impacts to the environment and protection of natural and man-made environmental values.

Considering the long-term period, the air traffic will be of considerable importance for the connection of islands' communes.The airport in Losinj requires qualitative improvements and the possibility of equipping for higher number of airplanes by additional technical elements and extending the contemporary services so as to be able to accept regular lines of smaller airplanes. The total surface area of airport, under the special regime, is planned over 27 ha, with the length of runway up to 1200, i.e. for the airport of 2B category. These regular lines could lines could have the seasonal tourist character, as well as the role of regular distribution of passengers from primary and secondary airports to Losinj, since the airports in Pula and Krk are in close vicinity. The airport in Losinj should be also directed in the sense development of sport and tourist activities, air-taxi, panoramic flights, searching services etc.

Organization and direction of the postal network in the planned period will tend to the more mass opening of the rational forms of PTT network i.e. separate organizational parts of sectors for providing PTT services. This way the existing structure and telecommunication network features will be gradually changed, making all forms of these services easier to access to the potential users, which has the essential importance for the smaller settlements. Besides the PTT organization model the apply of modern technology will face the essential changes in the exploitation of the mail traffic. Dislocated users of the outermost data terminals, electronic computer centres, users of videotext and teletext facilities will benefit from information transfer network. Telecommunication network will be modified and rationalized in the sense of applying of new technical system of commutation and transfer by introducing digital instead of analog transfer system.

Transportation system belongs to those social and economic activities which face the most dynamic development over the last century. Therefore, it is to expect that it will continue through the next century too, incorporating numerous technical and technological innovations.

So it seems to be inadequate and, without futurological prognosis even irresponsibly, just to translate the existing state of transportation system into 2050 or 2100 AD. describing how the climatic change will influence them.

Ships of hundred years ago cannot be compared with today's ships neither by the size nor by their power. Ferry-boats didn't exist then. Cars become a mass transport means only 70 years ago. The same works for airplanes, moreover, the ones of 30 years ago are even less comparable with these of today. It's all mentioned just because we simply believe that future transportation facilities and means won't face any essential constraints, which wouldn't be able to avoid expected climatic changes and impacts.

2.9.5 Suggestions for Follow-Up

There is a priority to create the data base no every possibly endangered transportation facility. It would comprise all relevant characteristics of those facilities, all the development programmes for renewals, reconstructions, adaptations, new buildings etc.

In addition, it becomes a necessity to collect all important information from the past period about general extreme climatic conditions and especially on occasional dynamic sea impacts to the transportation facilities (such as high sea levels and the conditions in which they appear, the strongest storms recorded in open sea or in the protected port aquatories etc.).

The system of continuous monitoring of future extreme climatic events, both general and local, should be established which would serve as extremely valuable basis for all the future engineering activities.

2.10 Health and Sanitation

2.10.1 Health

Actual situation of the diseases and mortality grade of the population in the Republic of Croatia and the Cres-Losinj islands regarding the usual trend until the end of this century

The estimation of the complexity of influence of the biosphere on the complexly reacting human organism is always a certain problem, especially if we talk about the estimation in longer periods of time. The human organism has various possibilities to adapt to changes and influences of its environment, and it necessarily needs a longer period of time to present those changes we call illness. It is necessary to emphasize that disturbances that show up in that period of time are more evident and more intensive the more are accentuated the biosphere oscillations in their speed of appearance and alteration.

Even if we neglect any possible bigger influence of climate and weather changes till the year 2100, the variation in morbidity and mortality due to environmental changes caused by influence of the "civilization" process, is pointing towards a change in today's pathology. That is shown in the long-term research study of the trend of the population's health-condition in our Republic and our archipelago, from 1961, during periods of two decades until the year 2000.

The present situation of the diseases of the islands' population (pop.No. 11.395) is as follows:

1. diseases of respiratory organs;
2. diseases of nerves and sensory organs;
3. diseases of heart and vascular system;
4. diseases of muscular and bone articulation system;
5. diseases of the skin;
6. injuries and poisoning;
7. malignant neoplasms.

The trend of diseases as mentioned above present in the entire population of the islands entirely correspond to the morbidity trend in the Republic of Croatia.

The diseases trend is slightly different among more sensitive children population. In this group the first place belongs to the diseases of the respiratory organs followed by diseases of nerves and sensory organs as well as infections and parasitical diseases, skin diseases, digestion diseases and at the end poisoning and injuries. Malignant neoplasms are quite rare. It is obvious, when speaking about children, that we find mostly acute and less chronic conditions.

Until the year 2000 we can expect an increase of respiratory system diseases, heart and vascular system diseases, as well as psychical disturbances and malignant neoplasms over the whole population.

Furthermore, we expect among children the increase of respiratory, nerves and sensory organs diseases as well as injuries.

Mortality grade of the islands' population is low, since yearly only about 127 people (1,11%) die. The main reason for death are heart and vascular system diseases (48%) followed by symptoms and insufficiently determined conditions (16,5%), malignant diseases (13,4%), respiratory organs diseases (11%) and injuries (1,5%).

Child mortality is extremely low. In the year 1990, for example, only two children died (1,5%) in neonatal period: such distribution is completely in accordance with mortality data in the whole Republic, only the numbers differ. We do not expect significant changes neither regarding the mortality number nor in the structure of death causes until the end of the century, but regarding a possible reduction of the presence of higher age groups as well as a decrease of the "symptoms and insufficiently determined conditions" thanks to the progress in medicine science. This means that heart and vascular system diseases will continue to prevail, as well as malignant neoplasms, respiratory and digestion organs diseases, especially the chronic ones.

Mortality of babies and infants on our islands is low and it is supposed it will remain as such. In the future we still expect early neonatal mortality which will be followed by inborn anomalies, respiratory system diseases, infections and parasitical diseases as well as "insufficiently determined conditions".

In children of higher age particular place shall have injuries and poisoning.

Expected influence of climate changes on disease and mortality rate of the islands' population

The changing of the thermo-hydrical complex, according to the estimations made by hydrometeorologists based on the results of local scales, an increase of the air temperature for about 1 °C could be expected in our region by the year 2050, and of about 3 °C by the year 2100. Herewith we expect a higher increase during the summer months, the so called "high season".

Precipitations, even if they would not change in their global quantity, they would increase during the period winter-spring and decrease stronger during the period summer-autumn. As such, a similar yearly scenario of increase of the air temperature and advanced distribution of precipitations should not have any special influence on the human pathology of the island inhabitants. However, there is still a possibility of extreme situations which means that a possibility of overheating the organism and heat-waves must be taken in consideration. That is extremely important for some risk-groups patients like hypertonics or cardiopaths and as well as babies and children. More explicit heat-contrasts could lead to appearances of short and destructive winds and down-pours because of the changing of the trajectory of the tropical cyclones. It is clear that such extreme conditions have to manifest themselves on the health of the population, especially regarding the traumatism. Theoretically, a stronger increase of temperature should manifest itself in the problem of drinking water supply of the population, even in our territory, the more as the decreasing of the Lake of Vrana water-level represents an extra and unknown problem. According to this, there is a fear of possible intestinal infections and digestion disturbs especially during summer. There are also to be expected more molestants which could lead to appearances of some illnesses prevalently of those they are vectors, as tick-encephalitis or papatachi-fever. These diseases could even reach real epidemic dimensions.

Mutations in the field of the photoactinic complex indicate a stronger accentuated ultra-violet radiation, especially ß-rays, which happens because of the dilution of the ozone layer in the stratosphere and which could have as a consequence an increase of skin malignancies, sight-problems (cataract, blindness). The same radiation quality change could render useless any further application of thalassotherapy in the curing process of some skin diseases as for example psoriasis.

Changes in the area of the chemical complex have a special importance. Losinj is known for having a very low level of air-pollution, meaning a low content of oxidants, smoke and dust sediments. The "greenhouse" gases could, according to an expected explosive increase of the population of the Earth, and the subsequently increase of traffic density, have its reflections on the structure and quality of the air inside it. Especially during the summer season and the so-called "inversions" of air heath which is determined by air mass stagnation, low clouds and weak air circulation. This could, as a consequence, reflect on the respiratory system, especially patients with chronic diseases with obstructive bronchopulmonary diseases, like bronchial asthma or chronic bronchitis, for whom Losinj represent a certain "oasis of health".

Permanent measuring of the acidity (pH) of the air, having been practiced for years in Veli Losinj, are indicating its more and more "acidity" as a consequence of long distance transport of pollutants coming from distant industrial areas that damage the flora and can strongly affect the quality of the air.

A particular problem with the foreseen considerable increase of population will represent the waste disposal on land and the waste-water going into the sea. This could lead to stronger mutations in the sea flora and fauna, for example frequent "flowering" of the sea and appearance of jelly-fish which can cause the increase of allergic reactions and skin damages.

So, if we accept these, luckily still hypothetic, suppositions about possible changes of the environment by the year 2100 we have to think seriously about the health of the entire population as well as of the population of our archipelago and undertake all possible actions for its sanitation, to be in time (if it is not too late already!)

Our local influence on changes of the thermo-hygric complex shall not be able to change them significantly because they belong to a rather wider domain. We should have a really good organization of health protection of resident population and especially during the "high season" with the possibility of a quick, safe and comfortable transport of patients to bigger medical centers (such as those in Pula, Rijeka and Zagreb). All necessary above mentioned presumptions already exist and are partially achieved. Furthermore, it will be necessary to organize an adequate forecast service to have information about the incoming storms, especially those followed by destructive winds.

The Vrana lake certainly represents a special, vital problem of the islands. Certain studies on the lake problems have already been made and they should be included in this very project. However, in the future it will be necessary to have a strict control over the water quality and to perform a continuous sanitation.

It is equally important to continue to devastate the molestant brood but not with past methods of insecticide dusting.

Events in photoactinic complex strongly exceed our local possibilities and enter into large international interventions. In any case, however, it will be an imperative to rise the health culture of the resident population as well as of the tourists, promoting about possible noxious influence of the environment (as for example excessive sunbathing) especially on individuals with premorbid conditions or with already developed diseases.

The most important activity will be to maintain the existing conditions of low air pollution. It is also important to forbid building of industrial complexes, even the smallest ones, permanently controlling or even closing the existing ones (Cres?). Furthermore it will be necessary to regulate (reduce?) car traffic and to dislocate the camping sites to more isolated places. If possible avoid heating with solid fuel.

The vast disposal area must have an adequate level not to pollute the environment. A special attention should be paid to the sewage system which is inadequate and partially outworn. The same attention should be paid to the hygiene of public beaches.

At the end I have to conclude with the contestation that however often we mention today the possible future climate changes and weather conditions and their reflection on the human environment seem to be unreal, we have to start pondering on the destiny of mankind and try to undertake everything possible to save what can still be saved.

2.10.2 Water supply

Past trends and present situation

The water supply system of the Cres-Losinj municipality derives its potable water from the Vrana Lake on the island of Cres. Lake Vrana as water phenomenon is the only fresh water resource of the Cres-Losinj archipelago. This lake is the speciality of the archipelago and makes it different to the other Adriatic islands. The total area of the lake is 5 km^2, maximal depth is 70 m (60 m below sea level) and it accumulates 220 millions m^3 of fresh water.

The existing system consists of the pumping plant of the total capacity of 262.5 litres per second (three pumps each of 87.5 litres per second) with the present pumping maximum of 150 litres per second. The water is pumped through the 620 m long and 200 mm diameter pressure line to the distribution storage tank "Vrana" of 2 500 m^3 capacity at +227 m above sea level.

The distribution of water from the storage tank to the consumers is carried out with two transmission mains: the Northern main directed to Valun and Cres and the Southern main directed to Osor, Mali and Veli Losinj.

There is a break pressure chamber on the Southern transmission main in Osor on +156 m above sea level. The Southern main crosses two channels 4 m below the sea level under the bridges (in Osor and Mali Losinj).

The settlements served by water supply system on the archipelago are: Cres, Valun, Martinscica, Orlec, Krcina, Loznati, Punta Kriza (only a small part), Osor, Nerezine, Cunski, Artatore, Sv, Jakov, Mali and Veli Losinj.

There are 6 462 connections to the water supply network of the residential population (about 11 000 inhabitants) and 936 enterprises.

The current demand of water is approximately 70 litres per second, reaching 150 liters per second during the summer season.

There is a distribution storage tank for each settlement (Table 2.10.2.1.). The tanks are located on 40 to 120 m above sea level (mostly +65 to +70 m) and the water reaches the consumers by gravity. The location of the distribution storage on the high levels enables the pressure in the water supply network of 5 to 6 bars.

According to the future water management plan for the year 2015. and to the Physical plan of the Cres-Losinj municipality (January 1991) adopted by Assembly of Cres-Losinj commune,the required quantities of drinking water are:

	for the Northern system	for the Southern system
resource possibilities (litres per second)	84	222
requirements(litres per second)	65	219
excess of water(litres per second) (can be used for the southern zone)	19	2

The distribution of water for settlements and the consumers is shown in the table 2.10.2.2. Maximum capacity of water supply from Vrana lake has been estimated at around 300 liters per second during the whole year.

The settlements which are not connected to the water supply system as well as the islands of Ilovik, Susak, Unije and Srakane, use the wells as the potable water. This water is used also for agriculture and sheep breeding. There is only a small fresh water resource, very sensitive to the weather changes, on the island of Unije.

During the dry summer period, because of the lack of water in wells, it is necessary to bring water either by truck tankers, or by tankers to those places.

Expected impacts of climate changes to water supply

According to the adopted climate changes scenario for the Cres-Losinj archipelago (See Table 2.1.5. Chapter Climate Conditions), the increase of the temperature and the rise of the sea level following impacts on the water supply system should be expected:

increase of temperature will increase evaporation trend and further decrease in the level of the Vrana lake could be expected which means that there is a possibility that the Vrana lake may not be able to satisfy the fresh water supply requirements of the Cres-Losinj archipelago;

sea level rise might influence the level of the lakes' salinity and thus affect its ecosystem and the use of the lake as water supply for the archipelago;

the storage tanks, the break pressure chamber and the transmission mains can't be affected by the sea level rise because they are located at least 20 m above sea level (till +227 m);

there is no possibility of impact to the submarine pipe because it is 4 m below the sea level;

concerning the water supply network and its installations (distribution points, house connections) in the coastal areas in Osor, Cres and other places will be flooded due to the sea level rise. Even today 5-10% of the total network very close to the shore during the tide periods is flooded;

he water supply pipes can't be damaged because they are constructed of sea water resistent materials. Due to the pressure 5-6 bars in the pipes the sea water cannot penetrated into them;

the sea level rise will cause higher costs for the maintenance of the water supply installations because of the corrosive atmosphere. Water connections in the houses of the coastal area will be affected;

according to the climate change scenarios the lesser rainfall in the summer will cause a shortage of available water in the areas supplied by wells. The sea level rise will cause a rise in the water level in wells located in the lower parts of the islands and will effect higher salinity of this water.

Suggestions for action to avoid or mitigate the effects

The water supply system is such a technological integrity that can not be very much affected by expected climatic changes, because the technology is adaptable to continuous phasic local requirements and the life- time of certain parts of the system is relatively short.This includes the pumping stations,the transmission mains and the water supply network. The distribution storage tanks are the lasting parts of the system and they aren't in danger because of the expected climate changes. The most vulnerable part of the system and in the same time the most important part in this chain is the Vrana lake. The climate change effects could effect the less quantities of drinking water than required. The table 2.10.2.2. shows that the requirements of the potable water for the commune Cres-Losinj in the year 2015. will reach the maximum capacity of the Vrana lake estimated before the new research works. As it is to be expected that the capacity of the Vrana lake will be lower than previous estimations,it should be necessary to find other ways for water supply for the year 2050 and 2100. This could be done either by bringing water from the mainland, or by producing drinking water from the sea water.

From the available quantities of water from the Vrana lake and the potable water requirements for the local population it is obvious that the development of this area will be tightly connected with the fact that there is a constant disproportion of consumption and production of water. The drinking water of high quality in the Rijeka microregion will always be the most required and vulnerable natural resource very important for the future development of local communities.

The use of water from the Lake Vrana should be better controlled and it is necessary to explore the water supply connection with the continent.

Because of the increase of temperature, larger areas in the mountains will be frost-free in winter and less water will be stored as snow which could have influence on the Lake Vrana if the origin of water is from the continent.

In areas supplied with well-water it may be necessary to find new sources of water supply or build reservoirs and storage tanks to collect and preserve rainwater for use during the dry periods.

Because there is no possibility to use the water of Lake Vrana for irrigation, it would be necessary to elaborate the reuse of water on the archipelago.

The water supply distribution points in coastal areas should be relocated towards inland. New installations of water supply systems should use corrosion (seawater) resistant materials.

Although there is a number of submarine springs with high flow in the coastal sea of the archipelago, it is not possible to use them because the technology for tapping, exploiting and managing these reservoirs is still not existent.

2.10.3 Sewerage System (Waste Waters)

Past trends and present situation

A small part of the islands is covered with a sewerage system which is mostly combined and in a bad condition.

There are 10 waste water basins form which five of them (Veli Losinj, Mali Losinj, Sv. Jakov-Nerezine, Miholascica - Martinscica and Cres) have part of the sewerage system already constructed or under construction. For the rest of the five basins (Valun, Osor, Koludarc and Artatore - Liska) only preliminary designs have been prepared.

There is a sewerage system and the preliminary treatment plant with a submarine outfall 800 metres long located in the harbour of Veli Losinj for the settlement of Veli Losinj and its tourist area.

Central urban part of Mali Losinj has combined sewerage system with short submarine outfalls of the Southern zone (30 metres in length, -17,0 meters depth) and of the Northern zone (20 meters in length, -10,0 metres depth). The biggest part of the town is discharging their waste waters to the septic tanks. The separate sewerage system is constructed only in the new zones of the town. The tourist zone of Cikat has its own sewerage system with submarine outfall of 130 metres which is not satisfactory and the tourist zone of Suncana uvala has a temporary submarine outfall of 200 metres long.

The area Nerezine and Sv. Jakov is a very attractive tourist zone with large ratio between the number of residential inhabitants and tourists. The only sewerage system has the settlement Bucanje with a sewer network, sedimentation basin and short submarine outfall. Settlement Nerezine has a combined sewerage system and is discharging the waste waters into the ground or via the so-called "black holes".

In the area of Martinscica - Miholascica the separate sewerage system is constructed only in the new part called Miholascica and a sewerage network for the auto-camp "Slatina" with discharge of the waste water through the submarine outfall 400 metres long.

The sewerage network in the town of Cres is combined and in a bad condition. The waste waters are discharged directly in the harbour with a few short outfalls. There is a special pollution problem with waste waters from the fish scanning factory "Plavica" and a slaughterhouse. The auto camp has its own sewerage network with an outfall of 80 metres which is unsatisfactory.

The present situation shows that concerning the waste water and rain water disposal in the commune of Cres-Losinj only a small part of the islands has sewerage network which is mostly combined and unsatisfactory. The most part of the network is in the centers of the towns and settlements and in the harbours. The pipes made of porous material, in the coastal area on the level of -1,0 to +1,0 meter are even today exposed to flooding and sea water gets into the system and causes pollution of the sea due to direct discharges. Some improvements in the construction of the sewerage system has been made by recent reconstruction works (for example in the town of Cres).

Only a part of the sewerage system in the new zones of Mali Losinj have separate sewerage system.

Expected impacts of climate changes to the sewerage system

The waste water sewerage system consists of truck sewer, collectors, pumping stations on the lowest levels, corresponding sewage treatment plants and long submarine outfalls with diffusors at the sea bottom at a satisfactory depth.

The system is calculated for the hydraulic pressure to the average sea level (+/- 0,00)to be able to give the best available results in the operations. Sea level rise will affects the hydraulic pressure more if the rise is higher and for a longer period. In case of a continuous sea level rise there could be serious inconveniences in operating of the waste water system. The main collectors and the pumping station are located in the coastal area with minimal declines. Due to the fact that the bigger part of the collectors is old, it would be necessary to check them in case of flooding. All pumping stations in the coastal area are designed according to the water consumption of the towns and settlements with dilution of strictly defined quantities of storm waters with automatic setting.

The overflow facilities of the pumps are scaled in hydraulic way for economic consumption of electric energy. The pressure lines leading to the sewage treatment plants are also scaled in hydraulic way for limited quantities of waste waters.and for the pressure gauge heights. The salty water is not aloud to be mixed with waste waters in the biological treatment plants.

The diffusors at the end of the submarine outfalls are scaled for respective pressure of the waste waters from the treatment plants and the respective pressure gauge height. Permanent disturbances in the diffusors of those pressures should be checked.

The sea level rise of more than 1,0 meter would particularly affect the sewerage system and waste water disposal in Cres and Mali Losinj. Taking into account the temporary tide, it could be expected, that the waste water system would not work properly or would be completely out of work and in addition the pollution of the coastal sea will occur.

The rise of sea level will additionally cause problems on the existing coastal sewage network. The increased rainfall (about 15 per cent in spring by 2050) will cause problems of excess water in combined sewage and storm water systems. The direct impact will be to increase pumping costs and pollution of the sea caused by dilution of the waste waters.

Intrusion of seawater into the sewerage systems, and outlets of storm waters and industrial effluents, may considerably interfere with their efficiency and function.

Suggestion for action

The existing sewage network in the coastal areas should be evaluated in the light of climate changes predictions and redesigned in such a way as to minimize seawater penetration. This review should encompass current development plans, design criteria, and modes of and materials used in construction. Separation of the floodwater drainage system from the sewage system and improved capacity of the storm water system to handle higher volumes of flow.

2.10.4 Solid Waste

There are 11 639 residential inhabitants in the commune of Cres-Losinj and around 80 000 tourists per year visit the islands. Tourism, agriculture, fishing and ship building are primary industries and waste producers in the islands. The total annual municipal solid waste quantity is 7000 tons per year. Industrial wastes must be added of about 500 tones per year.

According to the data obtained from the Communal Organization "Vodovod i Cistoca" - Cres ("Water supply and Waste Company" - Cres) the quantities of solid waste produced during the year could be estimated for:

-	the seasonal period (9 months)	500-700 tones per month
-	seasonal period (summer) (3 months)	700-1000 tones per month

The approximate composition of the municipal solid waste is as follows:

-	organic and biodegradable materials (food waste)	20%
-	paper	26%
-	textile waste	4%
-	plastics, rubber, leather	11%
-	iron, aluminium, etc.	5%
-	glass, inert materials	9%
-	wood	9%
-	sludge, sand, soil, etc.	16%
	Calorific value	4269 kJ per kg

About 50% of communal solid waste is disposed of on two land fill sites and the rest on uncontrolled sites mostly on the islands of Ilovik, Susak, Unije, Srakane and in some parts of Cres and Losinj. One is situated north-east of the settlement of Cres and the other is located on Losinj in the town of Mali Losinj (above the tourist zone Suncana uvala).

The existing landfill in Mali Losinj is approximately 20 000 m^2, with a depth of waste of approximately 20 m. Operation are hampered by the lack of cover soils for use as daily cover. There is no daily covering of waste now and this is causing serious vector, odor, and fire problems.

Expected impacts of climate changes to solid waste management

The rise of sea level will not cause problems on the existing landfills in Cres and Mali Losinj as they are located on the height of +200 and +100 m above sea level.

The flooding effects are expected in the coastal settlements on the solid waste disposal sides which are not regulated.

Due to the fact that existing landfills are not satisfactory it is necessary to select sites with future environmental conditions in mind.

Temperature elevations combined with decrease precipitation may lead to erosion of the topsoil, which is already relatively thin and it should be taken in consideration when planning and deciding the solid waste management system for the archipelago.

Table 2.10.2.1 The List of Distribution Storage Tanks

Distribution Storage Tank (name)	Existing Capacity (m^3)	Covering Percentage of the Daily Demand (%)	Total Required Capacity (75% of Daily Demand (m^3)
CRES	2,500	52%	3,600
VALUN	45	23%	150
LOZNATI	45	17%	100
OSOR	30	17%	130
NEREZINE I			
SV. JACOV	90 + 30	5%	2,000
CUNSKI	90	10%	680
M. LOSINJ			
CIKAT	750 + 4,000	62%	5,800
V. LOSINJ	1,600	89%	Satisfactory
MARTINSCICA	2 x 80	9%	1,350

Table 2.10.2.2

The demands for potable water for the commune of Cres-Lošinj until the year 2015							
Settlement/ zone	Inhabitants and tourist beds						Potable water requirements litres per second
	Residential	Hotels	Private accomod	Auto-camps	Nautical capacit.	Weekend visitors	
	Water standard l/day/person						
	200	400	250	120	150	250	
Porozine	40	-	200	-	-	120	1,1
Beli	125	120	-	400	-	355	2,4
Merag	25	-	200	-	-	125	1,0
Cres	5 000	4 000	3 500	4 000	2 000	2 100	55,5
Valun	130	60	440	-	-	150	2,3
Orlec	300	-	-	-	-	100	1,0
Zone Cres (north. zone)	5 620	4 180	4 340	4 400	2 000	2 950	63,3
Belej	180	-	-	-	-	150	0,9
Martinšćica	850	1 680	1 829	3 500	-	300	20,8
Osor	190	60	250	-	-	200	2,0
Nerezine	1 000	4 320	1 680	-	-	1 000	30,1
Pun. Križa	650	2 600	1 000	3 000	800	300	23,2
Zone Osor	2 870	8 660	4 750	6 500	800	1 950	77,0
Ćunski	380	1 500	500	-	-	400	10,5
M. Lošinj	8 500	8 300	6 000	-	3 500	2 600	89,2
V. Lošinj	1 600	2 200	1 400	-	-	1 000	20,9
Unije	190	60	540	200		700	4,6
Susak	190	60	690	-	600	1 200	7,3
Ilovik	250	60	540	-	1 000	200	4,8
Zone Lošinj	11 110	12 180	9 670	200	5 100	6 100	137,3
Total south. zone	37 980	20 840	14 420	6 700	5 900	8 050	214,3
Total north + south. zone	19 600	25 020	18 760	11 100	7 900	11 000	277,6
Other settlements	400	-	1 120	-	100	1 000	7,3
Total COMMUNE	20 000	25 020	19 880	11 100	8 000	12 000	284,9

2.11 Population and Settlement Pattern

Natural conditions of the archipelago area obviously refer to modest conditions of social and economic valuation of karst soil. Maritime position and possibilities for development of settlements on few favourable locations based on maritime affairs and fishery, are good, but those activities are of small and limited significance for the archipelago's geographic physiognomy until the establishment of a strong development of the new island's main pole of Mali Losinj.

Geographic physiognomy of the archipelago's area, with distinguished contrasts between afforested northern part of island of Cres, nearly bare rocky middle part and afforested southern part of island of Cres and Losinj - is the reflex of very long-range process of social and economic activity, primarily based on valuation of archipelago's karst soil. Number and position of prehistoric buildings/settlements,and even more the continuity of majority of the inhabited localities (which could be reconstructed from prehistoric and ancient times until today), is a very significant indicator for the close connections among island's population and the use of island's karst soil.

It's impossible to make the estimate on the total number of inhabitants on the Cres/Losinj archipelago for long-lasting periods of gradual colonization until the 16th century. It could be only confidently stated that the majority of population was concentrated on the island of Cres, while island of Losinj was quite low inhabited. In 1384 the old right of the oldest city of Osor (more than 4000 years continuously inhabited) was confirmed that the whole island of Losinj could be used as its, mostly pastured, area. The first traces of the two settlements on the island of Losinj are recorded in 1398 and they seemed to be of slight importance, such as Nerezine and cunski, and are not even mentioned as settlements those days.

Considering size, type and other features of all the settlements dated before the 16th century, there is no basis for presumption that they had been larger and more inhabited. The only exception is the city of Osor, which was reduced to half of its prior territory because of considerable decrease in number of inhabitants in the 14th and 15th century, what could be seen very well from the architectural remains of fortress. But, if the whole area of artificially transformed isthmus, surrounded by fortress in the old city of Osor, is taken into account, the number of inhabitants could have reached 2-3 thousand in the most favourable circumstances.

Venetian reports from the 16th century are therefore especially important as the first and relatively most reliable sources to estimate the island area colonization. All the sources show that the estimates on population number are quite credible. The report from 1553 recorded 6000 inhabitants including 1540 members of active population. In 1559 it is noticed that Cres/Losinj archipelago's area had 5560 inhabitants including 1040 members of active population. In 1572 5000 inhabitants are mentioned, while in 1591 5370 inhabitants are mentioned and the last reports noticed 4500 inhabitants in 1596.

The reports from the 16th century, similarly as for other parts of Croatian coast and islands, enable the first most reliable quantitative estimates about density of population of the selected island area.From the reports and real data it is obviously that archipelago's area had about 5000 inhabitants in 16th century. The decrease in the number of inhabitants is obviously connected with great economic crises, uncertainty and especially with the strong development of piracy along the Adriatic sea those days.

Venetian reports, besides other historic sources, don't mention migration flows.This area evidently wasn't the territory known for significant immigration with exception of immigration to Veli and Mali Losinj in the 17th and 18th century.Since the archipelago's area had 18000 inhabitants at the end of the 18th century, the increase during the two centuries under Venetian government mainly correspond to the rate of natural growth in other Croatian coastal areas.

The first systematically settled data of census in 1869 show the population flows in the last 120 years.The constant increase of the total number of the island's area population by the First World War, i.e. by the last Austrian census in 1910, and a sudden reduction after that to almost a half of it, is mostly the result of flows within the coastal settlements. Consideration of the development of density of population in the coastal settlements indicates the increase by 1910 wasn't the consequence of stronger development of centres of Mali Losinj and Cres.In the second half of the 19th century, as it is known, the definite concentration of maritime activities in Trieste and Rijeka finally stopped the prior considerable prosperity of Mali Losinj. The city of Cres, older than 2000 years, faced the stagnation,too.

It is obvious that the main cause for the increasing number of inhabitants is the increase of small coastal and hinterland settlements of rural character.Since the immigration, with the exception of individual flows, practically doesn't exist,it is obvious that the significant increase in the period 1869-1910 indicates to the significant natural growth.For the smaller outside islands this process of the population increase determined by natural growth continued even by 1931.

The urban centres (Mali Losinj and Cres) and coastal settlements were mostly affected by the sudden decrease of population in the 20th century.The hinterland settlements with the slightest economic development almost up to the recent date, i.e. by the census of 1961, were not exposed to the process of higher depopulation.But from that time, the processes rapidly accelerated so in 1991 in the hinterland settlements of archipelago lived only 7 per cent of the commune inhabitants.

The real appreciation of factors influencing considerable increase of population in the second half of the 19th century, and the stagnation and decrease in the 20th century, is very much possible through consideration of development of density of population according to the groups or zones of inhabitation, so as:A- inside settlements, B-all the coastal settlements, C- main island urban centres (Cres and Mali Losinj), D-coastal settlements with exceptions of Cres and Losinj, E- settlements of the smaller islands of Susak, Ilovik, Male and Vele Srakane.

Development of Population Number of the Commune of Cres-Losinj and development of Inhabitation According to the Physical Zones of Inhabitation in the Period 1869-1991

Group of Settlements	THE YEAR OF THE CENSUS						
	1869	1890	1910	1931	1935	1971	1991
A	2,423	3,426	3,841	3,173	2,720	1,535	821
B	14,767	14,098	14,636	12,764	7,388	8,454	10,975
C	10,331	9,614	9,580	7,649	4,903	1,823	2,234
(M. LOSINJ)	5,658	4,969	5,524	4,014	3,233	4,278	6,566
(CRES)	4,637	4,645	4,064	3,635	1,670	1,823	2,234
D (B-C)	4,348	4,484	5,048	5,115	2,485	2,353	2,175
E	2,002	2,594	2,783	2,918	2,400	668	424
Total commune	19,192	20,118	21,260	18,855	12,508	9,989	11,796

In the Commune of Cres-Losinj , Which comprises the area of 513 sq. km, lived 11796 residents in 1991,within 39 settlements of which 15 settlements directly at the coast, and the average density of population was 23 inhabitants per sq.km.

This island group is among Croatian islands with lowest population density, and as a commune it is among last in the Republic of Croatia.Such a low population density is a consequence of poor conditions of socio-economic development, meaning especially the unfavourable soil structure, the lack of valuable fertile soil and pretty bad transport connections with the mainland.

The population density within the whole commune , listed according to the island groups with regard to the change in the recent 20 years (1971 - 1991) could be seen from the following indicators:

Physical Integrity Islands	Area in sq.km	Number of Inhabitants		Population density Inhabitants	
		1971	1991	1971	1991
CRES	404	3,536	3,238	8.7	8.1
LOSINJ	75	5,786	8,134	77.1	108.5
SMALL ISLANDS	34	668	424	19.6	12.5
COMMUNE	513	9,989	11,796	19.5	23.0

The distribution of population in 1991 doesn't seem to be any better in comparison with general historic picture of inhabitation for this island commune.The population density has the trend to decrease both on the island of Cres and on the smaller islands, but it rapidly increases on the island of Losinj. The fact that 7560 inhabitants or 64,1% of the total population of the commune live in the cities of Mali and Veli Losinj, i.e. that more than 9764 inhabitants or 83% of the total population live in the settlements of Cres, Mali and Veli Lo{inj can prove the previously mentioned fact.

In 1991 altogether in 15 coastal settlements lived 10975 inhabitants or 93% of the total population of the commune.The rest of 24 settlements in the hinterland were populated by only 7% of people of the commune.The most important coastal places (10 settlements) with their valuable historic heritage along the coastline, were inhabited by 10939 people or almost 100% of the population living in coastal settlements in 1991.

In the period among census of 1971 and 1991 a considerable increase in the number of inhabitants was noticed (from 9989 to 11796 inhabitants).Although the present state is still only a half of the number registered in 1910 (21260 inhabitants), the signs of stabilization in demographic processes and gradual population increase are evident.

The compensation of demographic lacks (permanent and seasonal manpower) is mainly provided by immigration from hinterland of the Republic, which however is not the guarantee for qualitative population reproduction.This fact is proved by fact that the share of young population decreased in that period among two censuses, while the share of middle-age active population increased.

Analyzing the migration flows of the commune (comprising the physical flows and natural flows of the population/natural growth) it could be seen that in the period 1953 - 1971, the commune had characteristics of exodus type with negative migration flows, but of diverse intensity.In the period 1953 - 1961 commune had the strong depopulation characteristics, and in the period 1961 - 1971 the characteristics of dying out.In the period 1971 - 1991 the commune became an emigration type,i.e. commune of emigration regeneration.

The consequence of analysis concerning flows of number of inhabitants of the commune, is that not only political changes influenced the changes in population number, but due account should be taken of the socio-economic factors. No matter how much the natural fluctuation had the influence to the decrease of number of inhabitants, the main factor for the decrease is emigration.

Yet at the recent time, under the influence of immigration connected to the socio-economic development of the commune (especially the development of tourism), the number of inhabitants increases and a very slow change in the structural features of inhabitants occur.

The area of commune of Cres-Losinj was inhabited by old population in 1981, i.e. by the population of very old age with the rate of age of 0,856 which gradually improves/become younger in 1991.The number and the share of the middle-age population is in increase, and the share of young and old population is in decrease.

The lowest rate of age has the communal centre of Mali Lo{inj and Veli Lo{inj, a bit higher has the communal centre of second importance - the city of Cres. In all the settlements the rate of age was reduced in the last decade.In distinction from those three settlements, the rate of age is in increase in the rest of the settlements and is quite high and the percentage of old population is pretty high.

The oldness and depopulation of the commune are the result oh high rate of mortality which could hardly be mitigated by natality, i.e. by fertility of young population.The more convenient age structure of the population and better reproductive power in the commune has the island of Losinj, the island of Cres has the transient character, and all the small islands have the most inconvenient age structure.

At the area of commune there is only one working centre,Mali Losinj, which accepts 100 and more active daily migrators. In 1986 in the enterprises and private enterprises about 5550 working people were employed (about 41% women): 4% in primary activities, 145 in secondary activities, 64% in tertiary activities and 18% in quartiary activities.

The share of agricultural population is in the constant decrease (in 1971 about 14%, in 1981 about 6% and in 1991 about 3%). Today agriculture is not within the more important economic activities of the commune. The older population is mostly oriented to this activity, and mainly for their own needs.

Through analyses and contemporary comparison of characteristic selected demographic indicators (1981), the unique picture of demographic situation in particular settlements of the commune was determined.These indicators show their quantitative,i.e. vital, dynamic, socio-economic and other characteristics of the settlements. Through such analyses the demographic features for the particular settlements were realized,and it is also pointed out at the possibilities for interventions, i.e. for the sanation of negative processes in the settlements.It comes out from the analyses that in the commune of Cres-Losinj only three settlements (Mali Losinj, Veli Losinj and Cres) have favourable or satisfactory demographic picture, where 82% of the total communal population lived. The rest of 36 settlements have unfavourable demographic figures, having 18% of communal population.

The process of urbanization of the settlements is not associated only with the appearance of cities and their development (as it could be assumed), but also with complex changes in the urban and rural integrity,it follows the differences among urban and rural integrities which are expressed in demographic, socio-economic, functional and physiognomy changes.The process of urbanization was initiated by tourist development, better transport connections with the mainland, infrastructure of higher quality etc.It didn't affect all the island settlements in the same measure.

The settlement of Mali Losinj has the status of urban settlement, Cres has the status of settlement with urban character, 8 settlements have the status of better urbanized areas, while 9 of them have the status of lower urbanized areas. 20 settlements have the status of rural settlements comprising 7% of communal population.

Expected effects and most vulnerable systems and activities

The changed climate conditions will have determined, although limited, effect on distribution and dynamics of population in the coastal zones of macroregion of Rijeka and commune of Cres-Losinj, especially in the closer future by 2030 and 2050 AD.Naturally, it is plain that timely measures will have to be taken to protect housing parts of cities and settlements immediately on the coastline.

Dynamics of natural growth of population, according to these estimates, won't suffer any essential changes caused by sea level rise and climate changes, but it will follow the existing trends of extent of coastal regions all over the Republic of Croatia.Mechanical growth of population caused by present process of littoralization is not likely to be affected, at least not in the close future.

The change in trend of overall growth of population in the coastal regions of Croatia are not expected as well, since population situated in the affected areas represent quite a small percentage of the whole population, and gradual vulnerability through the longer period of time enables the possibilities to adapt.

The natural growth of population is under stronger influence of other factors such as social standard increase, economical power increase, level of health services, cultural level, religious customs etc. Migration flows are strongly influenced by relocation of poles of development to the areas with trend comparative advantages. Therefore, the total number of inhabitants in the coastal areas of macro-region of Rijeka and commune of Cres-Losinj will continue to follow the influence of existing trends. however, distribution or rather redistribution of the population living next to coastline, being very common case in coastal settlements and cities, will experience the manifestations of climate change conditions especially in the period 2050-2100 AD. That will, however depend on local features of coastal configuration as well as the structure of every particular settlements, but it is not expected to exceed more than 5-10 per cent of the population living in the coastal settlements of the commune.

It is likely that expected climate change won't decrease the foreseen speed of littoralization, but process of urbanization will probably by modified by natural resources, as for reduced water supply, water of lower quality, needs for higher treatment of potable water, water supply ensured from distant resources, higher level of treatment of waste water and its reuse. That will necessitate considerable investments into required infrastructure constructions in the coastal cities and all of this will result in higher costs of living in the coastal cities and settlements.

The temperature elevation during the summer months will cause the living conditions being less convenient, especially on the unprotected city places, when unpleasant mid-day heats will be more frequent. It is for serve that it may change the customs of both the local people and temporary tourists.

Prolonged yearly period of unpleasant heats will influence also the morphology (urban organization of towns and settlements), and will certainly reflect into the topology of residential buildings construction and other urban buildings. What kind of urban and architectural features will have the future building of towns/settlements and buildings could be situated even now in the areas of halter Mediterranean countries having the average annual temperature similar to the expected climate changes.

It could be predicted that future building of cities/settlements will follow the traditional building features dominating on these areas, which always took care of climate characteristics and impacts of it into people's community.

The expected decrease in precipitation will necessitate very strict way of management over the available quantity of potable water, water for domestic and communal needs (maintenance of urban green sp--- and communal services). If the problem of greater needs of water couldn't be solved by resources of water, the temperature increase and this higher evaporizátion will cause greater demand for water.

All this stage of preparing study, having no detailed research outlets from other substantive sections (dynamics of waves, sea currents, winds, processes in aquatories of bay of Cres and Mali Losinj etc), the emphasis of this part of study has given to identify the impacts of static (and dynamic according to our assessments) sea level rise, on all the man-made values in the area of commune of Cres-Losinj.

The special care was given to distinguish and to determine which buildings and infrastructure or technological systems already existing (in the parts of cities up to 2 m above sea level) will experience period of great but gradual changes of significant sea level rise by 2050 and 2100 AD.

Sea level rise is expected to cause the impact in the most significant scale on the settlements and economic activities which take place in the bay aquatories. Within the commune of Cres-Losinj exists the most important conurbation agglomeration on the Adriatic islands,i.e. settlements of Mali and Veli Losinj (about 7500 inhabitants in 1991).There are also the valuable historic cities of Osor (older than 4000 years) and Cres (2200 inhabitants), and the settlements Donje Selo-Susak and Ilovik.

In the cities mentioned above, the sea level rise will significantly affect urban life in their central historical parts.All these settlements have their oldest and most vital urban parts next to seaside: ports and city squares,walking zones-the centres of social and economic life.

Since it is the "lucky" case that these central parts are not yet settled in the proper way, these findings could serve as the basis for directions and conditions to determine adequate building operation.That means raising of communal infrastructure,qualitative arrangements of squares, coastal roads and buildings,ports and coastal facilities, etc.

All the other urban economic activities and infrastructure systems related to the coastal areas and sea (sewerage outfalls, undersea energy and telecommunication cables etc) won't suffer because of sea level rise or it will be relatively simple through the reconstruction or new building to avoid the negative impacts over the longer time period.

Determination of vulnerable areas and buildings (1991)

	Settlement or its part, tourist or economic zones	Vulnerable areas threatened by sea (ha)	Number of affected building	Length of built coast m1	Length of affected beaches in settlements or tourist zones m1
1.	**MALI LOŠINJ**	11,5	137	2.150	-
	Sv. Martin	1,0	12	250	-
	Kovčanje	-	3	150	-
	Artatore	-	5	40	300
	Čikat	-	-	110	1.100
	Sunčana uvala	-	-	120	300
	TOTAL	12,5	157	2.820	1.700
2.	**CRES**	12,0	182	1.190	-
	Kovčanje	0,2	-	200	500
	Melin	0,2	-	70	300
	Grabar	0,3	8	300	-
	TOTAL	12,7	190	1.760	800
3.	**VELI LOŠINJ**	1,2	37	350	-
	Rovenska	1,1	24	450	100
	TOTAL	2,3	61	800	100
4.	**NEREZINE**	2,1	37	400	2.600
	Bučanje, Lopari	-	-	-	-
5.	**SUSAK**	1,2	96	130	330
6.	**ILOVIK**	0,7	30	350	-
7.	**UNIJE**	0,2	14	120	300
8.	**OSOR**	0,7	-	350	200
9.	**MARTINŠČICA**	-	12	260	1.700
	Miholaščica	-	-	-	-
	Slatina, Tiha	-	-	-	-
10.	**VALUN**	0,8	16	220	400
11.	**PUNTA KRIŽA**	0,2	5	80	200
	Pogana	-	-	-	-
	Baldarin	-	-	-	-
12.	**POROZINA**	-	-	80	100
	TOTAL	33,4	618	7.370	8.430

Number of inhabitants (1991)
living in vulnerable parts of coastal settlements

1.	Mali Lošinj	about 450
2.	Cres	about 600
3.	Veli Lošinj	about 100
4.	Nerezine	about 100
5.	Martinšćica	about 30
6.	Porozina	-
7.	Osor	-
8.	Valun	about 50
9.	Miholaščica	-
10.	Susak	about 70
11.	Unije	about 30
12.	Ilovik	about 70
TOTAL: 1000 - 1.500 or 13% of population		

2.11.1 Development strategy for the considered island group in the changed climate conditions

The commune of Cres-Losinj has the completed Physical Plan for the planning period by 2015 , which established essential strategy directions of the development of population, settlement pattern, economic activities, land use and land protection.

Since the basic objective of this study is to suggest the future physical strategy of development of the Cres-Losinj archipelago,it is necessary for some directions to be reviewed or adapt to the expected climate change, especially considering the sea level rise.Naturally, due account should be paid to the durability of particular architectural undertakings and technological obsoleteness of specific infrastructure systems, so as to spread the costs induced from adaptability of coastal zones over longer period of time.

Some engineering undertakings (such as bank construction or representative public buildings) last over more decades, even centuries, while some require continuous reconstruction and adaptation to the new technological innovations.

Therefore, it is essential to include even now the relevant social, political and economic decision makers to participate in the land-use planning decisions, and direct them to think of causes and results which might come out of predicted global changes.

It is especially important, in the light of fact that all the decision maker structures,from political and economic communities at regional and local level, react more efficiently on immediate events expected in a few years and neglect those which are expected in the period of some decades or even a century.

Although the awareness of danger caused by climate changes already exists within research cycles, it still isn't present enough in most of the structures at national and regional level, being mostly unknown to those structures planning development and participating closely in the economic activities of local communities.

The public is informed more or less, but treating it in a way of science fiction.And, the way from identifying the problem to the strategy for avoiding the consequences is long and difficult, since it is necessary to include in it every activist at the relevant decision level.

The essential role in all mentioned above could play the development physical plans (physical plan of the commune and master plans of cities of Cres, Mali and Veli Losinj),which already contain some directions for adaptation, but will have to be necessarily changed and revised.

In the existing physical plan it is established that system of central settlement determines the relations between communal centre of Mali Losinj, communal sub-centre of Cres (bipolar communal development) and local settlements, side settlements and other communal settlements.

Local central settlements and the settlements of lower order have the function of initiating the development of their gravitation areas.This plan determines eight functional development areas or zones with its respective centre.

The system of central settlements in the commune of Cres-Losinj is determined by applying optimalization criteria, which alongside the economic effects,takes into account also the historical continuity and cultural tradition of particular centres.

In order to the implementation of polycentric development of the area,long-term development of economic structure and central functions are directed to the suggested settlement pattern at a number of smaller centres (local and those of lower order).

In the performing of the polycentric development in the area this plan is stimulating the rational extent and management of building land in the local central settlements and other settlements which appear to be focal points of particular development programme and into which is priority oriented future housing.Thus the migration flows are directed in time and space in accordance with objectives of polycentric urban policy.

In the process of raising all the central settlements insufficiently used parts of them will have to be priority used,and particularly those requiring urban reconstruction.In the frame of existing parts of cities and settlements, future housing should be carried out by interpolation or extension of the existing ones. Protection and urban renewal of present stock of dwellings should develop as a continuous and planned engineering activity, worth at least as well as new residential building.

The building land of existing settlements within the vulnerable coastal belt next to the seaside, could extent only inland, both for housing and other building. Into the continuous protected coastal belt all the coastal settlements are included.

Tourist building, housing and other construction in the coastal area of the commune is by this Plan directed inland by applying principles of decentralized concentration building, which assures free spaces of natural values between built-up settlements or tourist complexes.

Organization of secondary housing is based on the principle of concentrated construction within the building land of cities and settlements or is directed into the parts of existing settlements which don't seem to have any other development possibilities. In the valuable historic sites, secondary housing should be directed to reconstruction or adaptation of existing stock of dwelling. Tourist building is directed mostly into "open" zones by this Physical Plan. These zones -tourist complexes are of such surface area that they enable the implementation of planned capacities.In these zones should, first of all, start the continuous process of reconstruction of tourist bearing capacities, aiming to the higher quality including contemporary services.

Development Prognosis for population of Republic of Croatia, on the basis of present trends and estimates of international migrations

	1931	1948	1991	2050	2100
R. of Croatia Total:	3.705.455				
population		3.779.858	4.784.265		
rate 1931-91		0,39%			
On the rate /trend 1931-91				6.022.000	7.319.000
Development prognosis for population (correction because of war losses 1941-45)				6.500.000	8.000.000
or increase 1991 - 2100 for 68%					

In vulnerable coastal settlements in the commune of Cres-Losinj, a number of residents is/would be

		1991	PPO C-L 2015	2100
1.	Mali Lošinj	6.566	7.000	total 16.000 to 20.000 inhabitants
2.	Cres	2.234	4.000	
3.	Veli Lošinj	994	1.200	
4.	Nerezine	397	800	
5.	Martinšćica	186	700	
6.	Porozina	3	30	
7.	Osor	80	150	
8.	Valun	68	100	
9.	Miholašćica (included in Martinšćica)			
10.	Susak	188	150	
11.	Unije	81	150	
12.	Ilovik	145	200	
Coastal settlements total:		10.965 93%	13.780 86%	20.000 80%
Commune total:		11.796 100%	16.000 100%	25.000 according to republican trend

Trends and measures for physical planning and management of vulnerable areas

As a possible proposal of such course of measures the following could be accepted:

1 the public, political structures and decision makers at all the levels (including the economic structures) should get know of possible successive consequences caused by changed climate conditions and of needs for measures to be taken in order to avoid them;

2 pointing out to the necessity of actions for fighting against the consequences should become national action, which cannot be left only to the local government of the region and commune;

3 research of local conditions, such as inventory taking of coastal areas and local impacts of sea level rise and temperature onto waters, soil precipitation and substantial socio-economic activities;

4 intervention strategy capable to react on possible climate change conditions should be developed in the first phase, but taking into account continuous fluctuations of these conditions, since the investment strategy wouldn't be reasonable in the period of minimal impacts (sea level rise of only 20 - 50 cm).In a few years or few decades further investments should be taken in order to defend of following sea level rise;

5 establishing of cost-benefit analyses and adapted method Environment Impact assessments for qualifying the efficiency of every investment with the aim of avoiding climate change impacts, so as to protect certain vital interests at any cost;

6 researches of technological solutions for avoiding mentioned impacts at local, regional and global level, exchange of experience;

7 identification and assessment of risks for coastal zones, islands and vital resources in the terms of sea level rise of 0.3 - 0.5 m by 2050 and 65+35 cm by 2100.

LEGEND

1. IDENTIFICATION OF VULNERABLE PARTS OF SETTLEMENTS, ZONES AND BUILDINGS WITH REGARD TO THE PREDICTED SCENARIO FOR THE TIME PERIOD BY 2100
MAX SEA LEVEL RISE OF 65+/-35 CM WITH NATURAL SEA EVENTS (TIDES, WAVES, WIND) UP TO 100 CM
TOTAL MAX EXPECTED SEA RISE UP TO 200 CM

1.1 SETTLEMENT PATTERN

COMMUNAL CENTRE (MALI LOŠINJ)

COMMUNAL SUBCENTRE (CRES)

LOCAL CENTRE (VELI LOŠINJ, NEREZINE, MARTINŠĆICA)

SECOND ORDER CENTRE (ILOVIK, SUSAK, UNIJE, OSOR, VALUN)

OTHER SETTLEMENTS (POROZINA, MERAG)

PROTECTED ARCHITECTURAL ENTITIES

1.CATEGORY OF PROTECTION - CRES, OSOR

2.CATEGORY OF PROTECTION - ILOVIK, NEREZINE, UNIJE, VALUN, M.LOŠINJ, V.LOŠINJ, SUSAK-D.SELO

1.2.INDUSTRY AND ENERGY

SERVICE FOR BOATS - SHIPYARD (CRES, NEREZINE, M.LOŠINJ)

COMMUNAL ZONES (KOVČANJE)

1.3.TOURISM

COMMUNAL TOURIST CENTRE (M. LOŠINJ, CRES)

IMPORTANT TOURIST CENTRES - DEVELOPMENT AREA'S CENTRE (V. LOŠINJ, NEREZINE, MARTINŠĆICA)

OTHER TOURIST CENTRES - DEVELOPMENT ZONE'S CENTRE (ILOVIK, SUSAK, UNIJE, OSOR, VALUN)

BATHING-PLACES (NEXT TO SETTLEMENTS AND TOURIST PLACES)

NAUTICAL FACILITIES

NAUTICAL CENTRE (M. LOŠINJ, CRES)

MARINA (NEREZINE, ILOVIK)

TOURIST PORT (SUSAK, V. LOŠINJ)

SMALL HARBOUR (VALUN, MARTINŠĆICA, UNIJE, OSOR)

1.4. TRANSPORT SYSTEM

ROAD TRAFFIC

REGIONAL ROAD R-2760 - ISLAND MAIN ROAD

BUS STATION (CRES, M. LOŠINJ)

PETROL STATION (CRES, M. LOŠINJ)

LIFT BRIDGE (OSOR, M. LOŠINJ)

MARITIME TRANSPORT

MAIN PASSINGER PORT (M. LOŠINJ)

PASSINGER PORT (CRES)

LOCAL PASSINGER PORT (UNIJE, SUSAK, ILOVIK, MARTINŠĆICA)

CARGO PORT (KOVČANJE)

FERRY TERMINAL (MERAG, POROZINA, M. LOŠINJ)

BANK FACILITIES (OPERATIONAL PORT, MOLE, BANK ETC.)

1.5. OTHER INFRASTRUCTURE SYSTEMS AND SERVICES

WATER SUPPLY AND WASTE DISPOSAL

PUMPING STATION

SUBMARINE OUTFALL

2. POSSIBLE PHYSICAL IMPACTS ON THE BASIS OF PREDICTED SCENARIO WITH MAX SEA LEVEL RISE AND NATURAL SEA ACTION BY 2100

PREDICTED AREAS OF TEMPORARY FLOODING (2.0 M)

PREDICTED AREAS OF PERMANENT FLOODING (1.0 M)

VULNERABLE BANK FACILITIES

3. ASSESMENT OF POSSIBILITIES TO PROTECT VULNERABLE PARTS OF SETTLEMENTS, BUILDINGS AND ZONES

INTERVENTION AND PROTECTION ZONES

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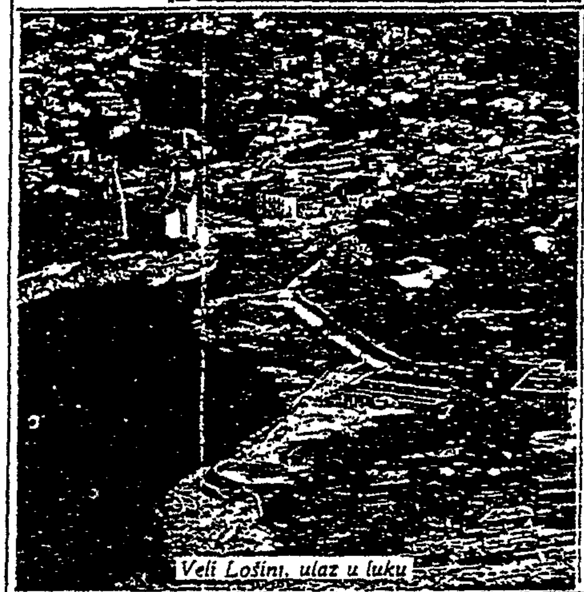
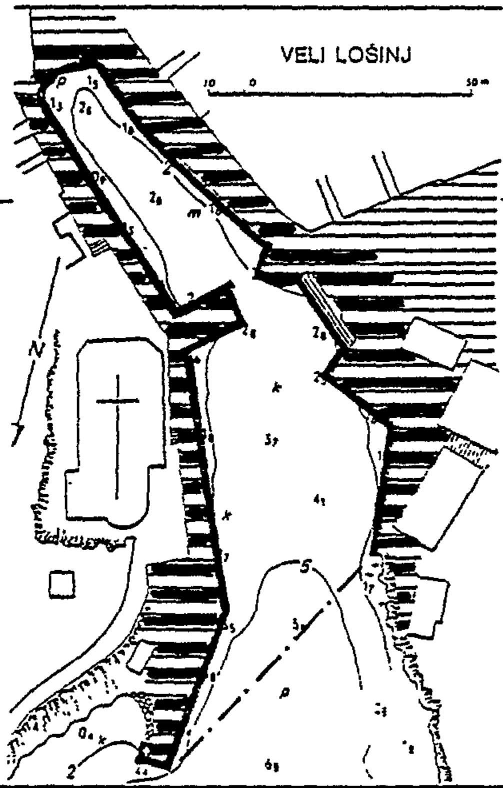
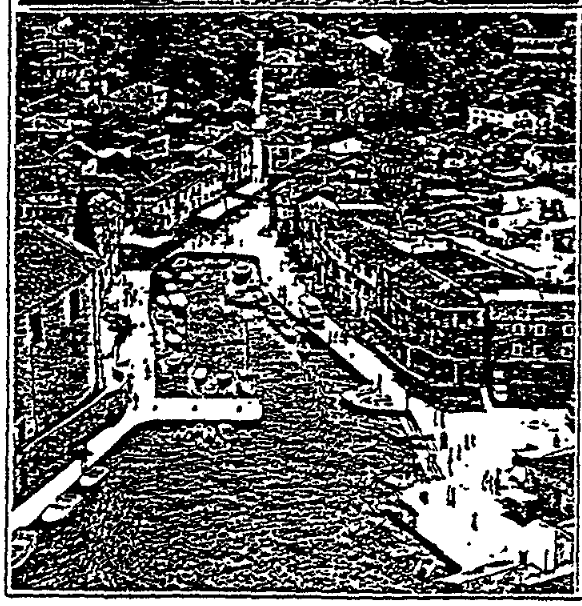
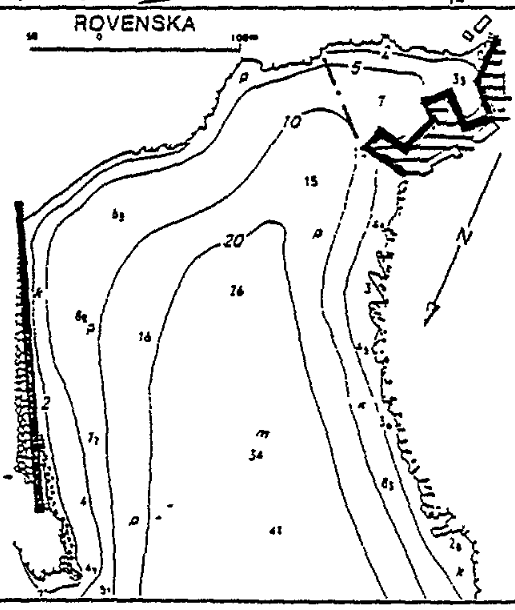




Veli Lošinj, ulaz u luku





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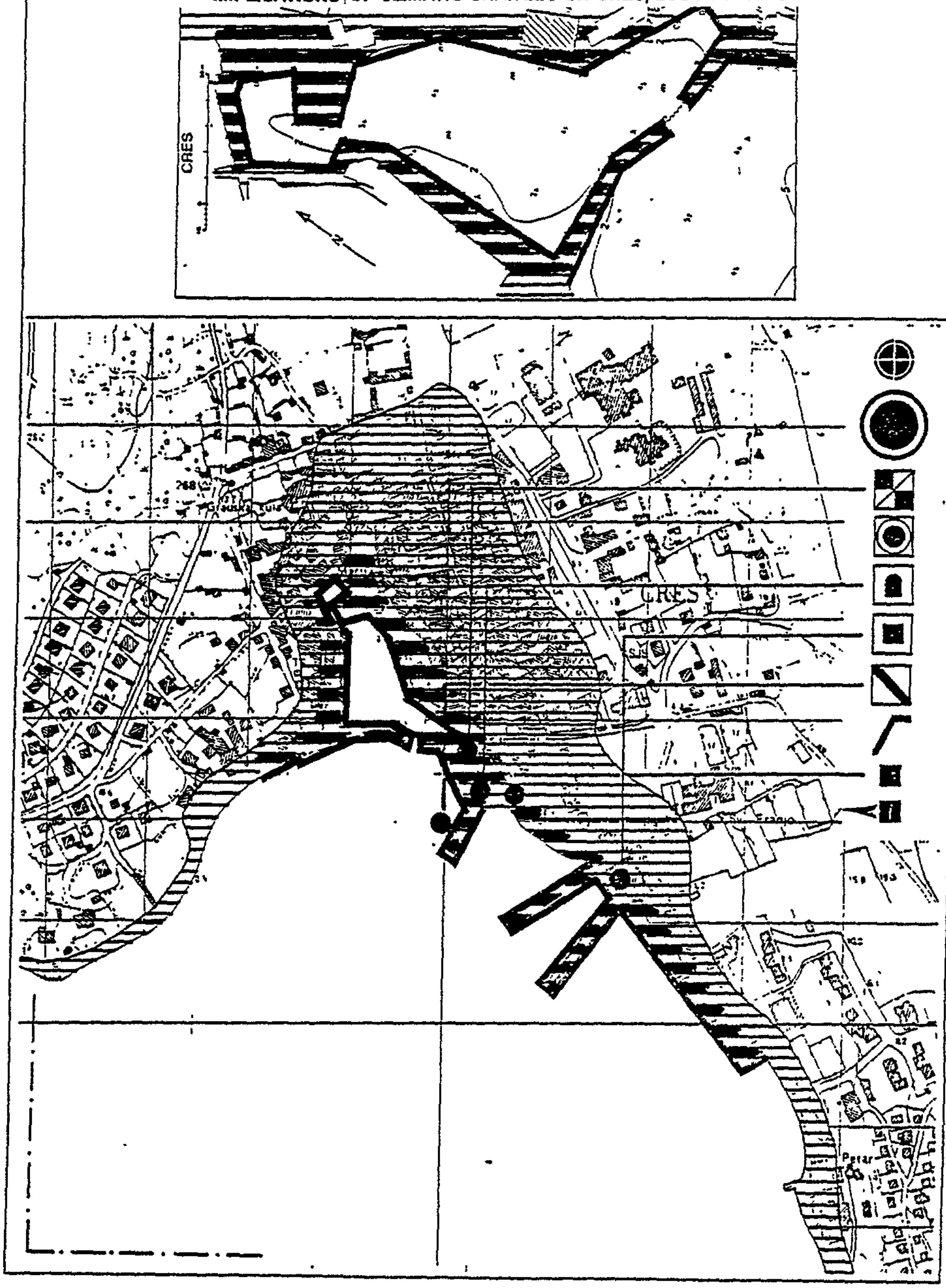

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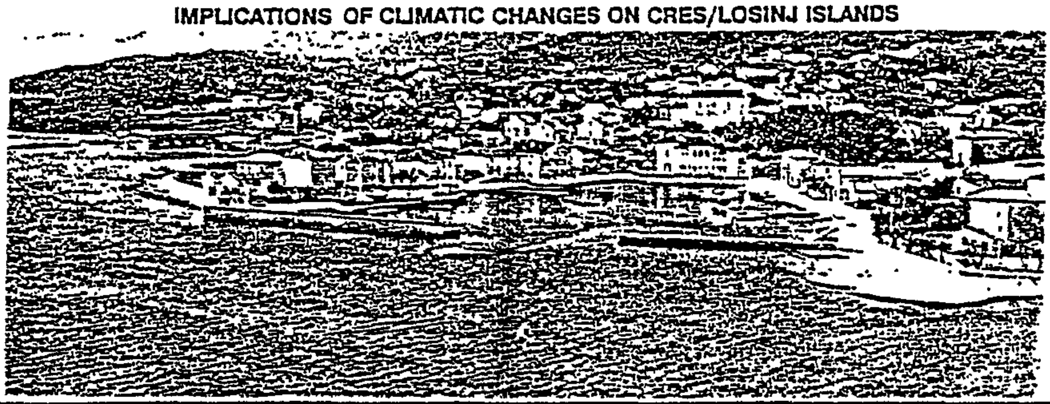

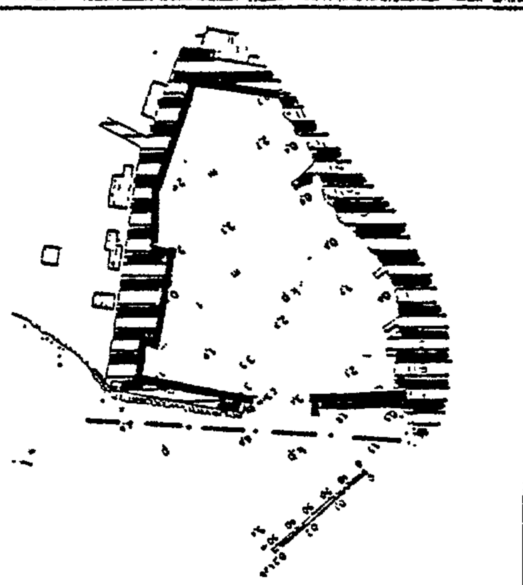

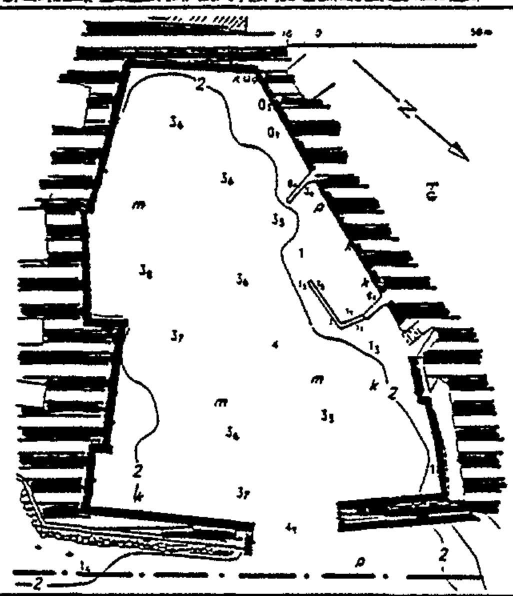

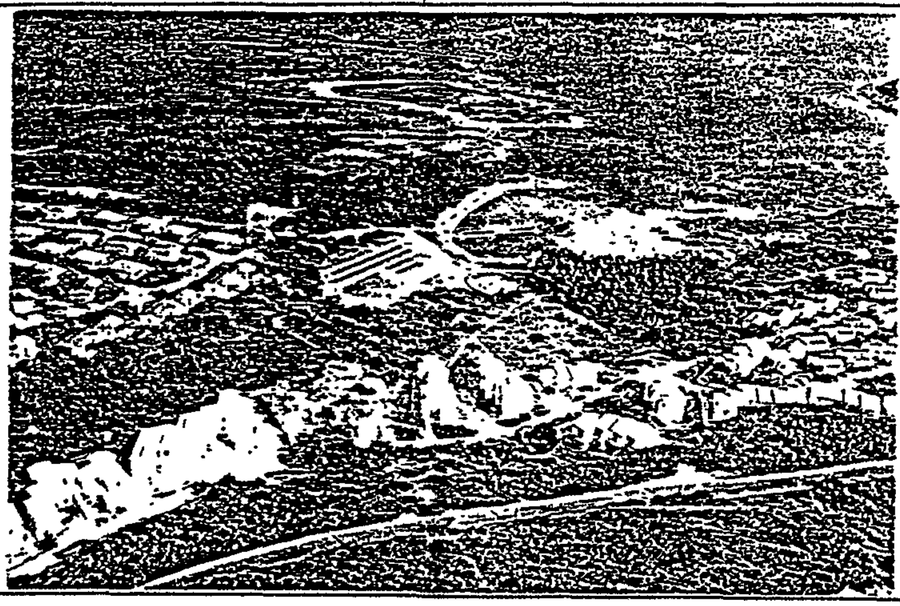

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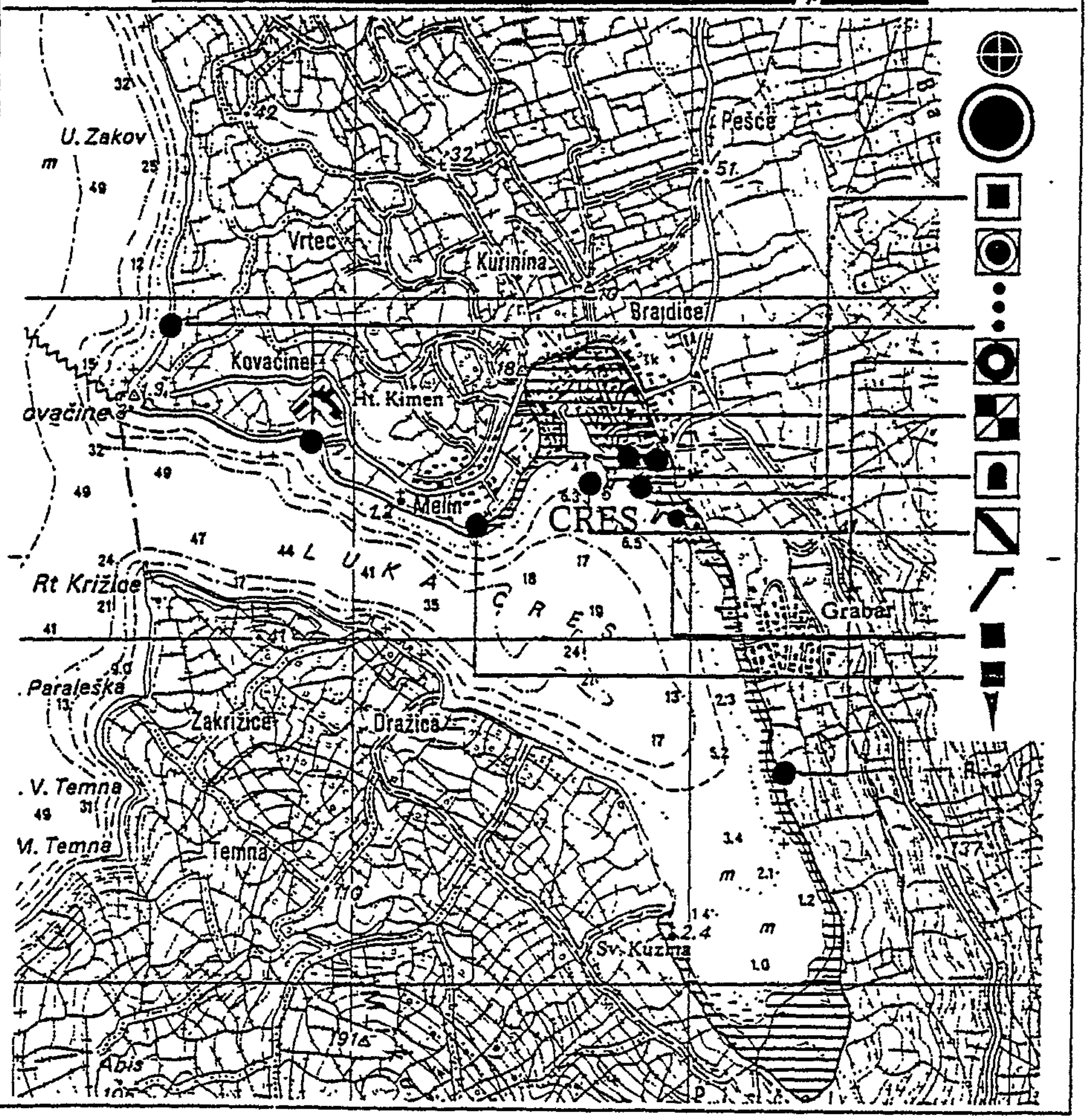

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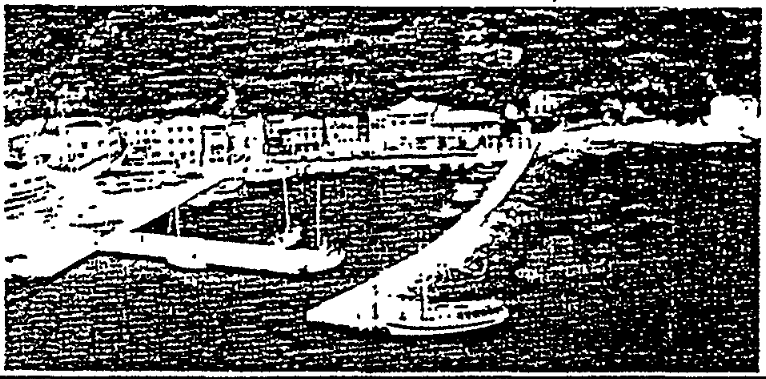

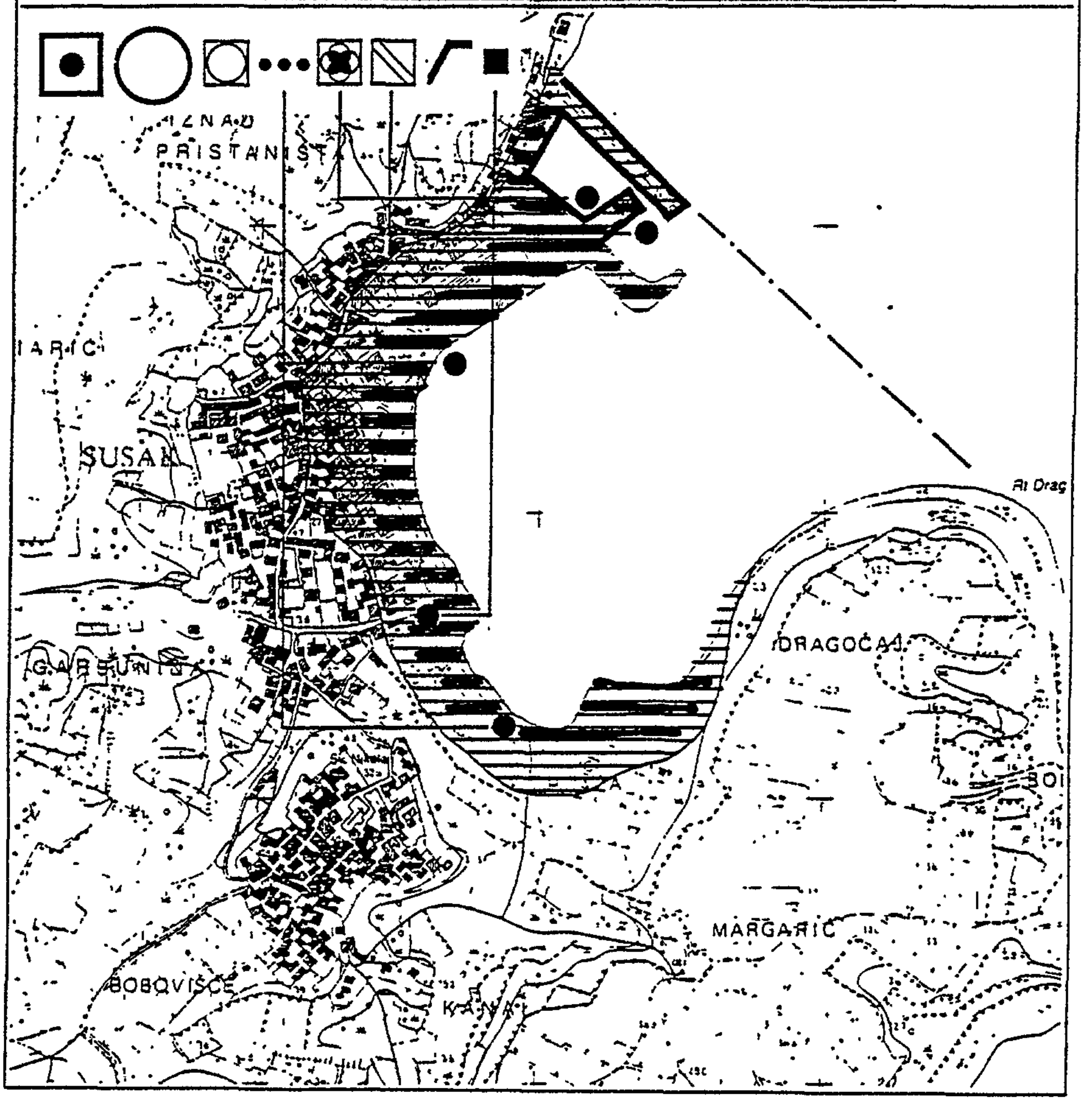

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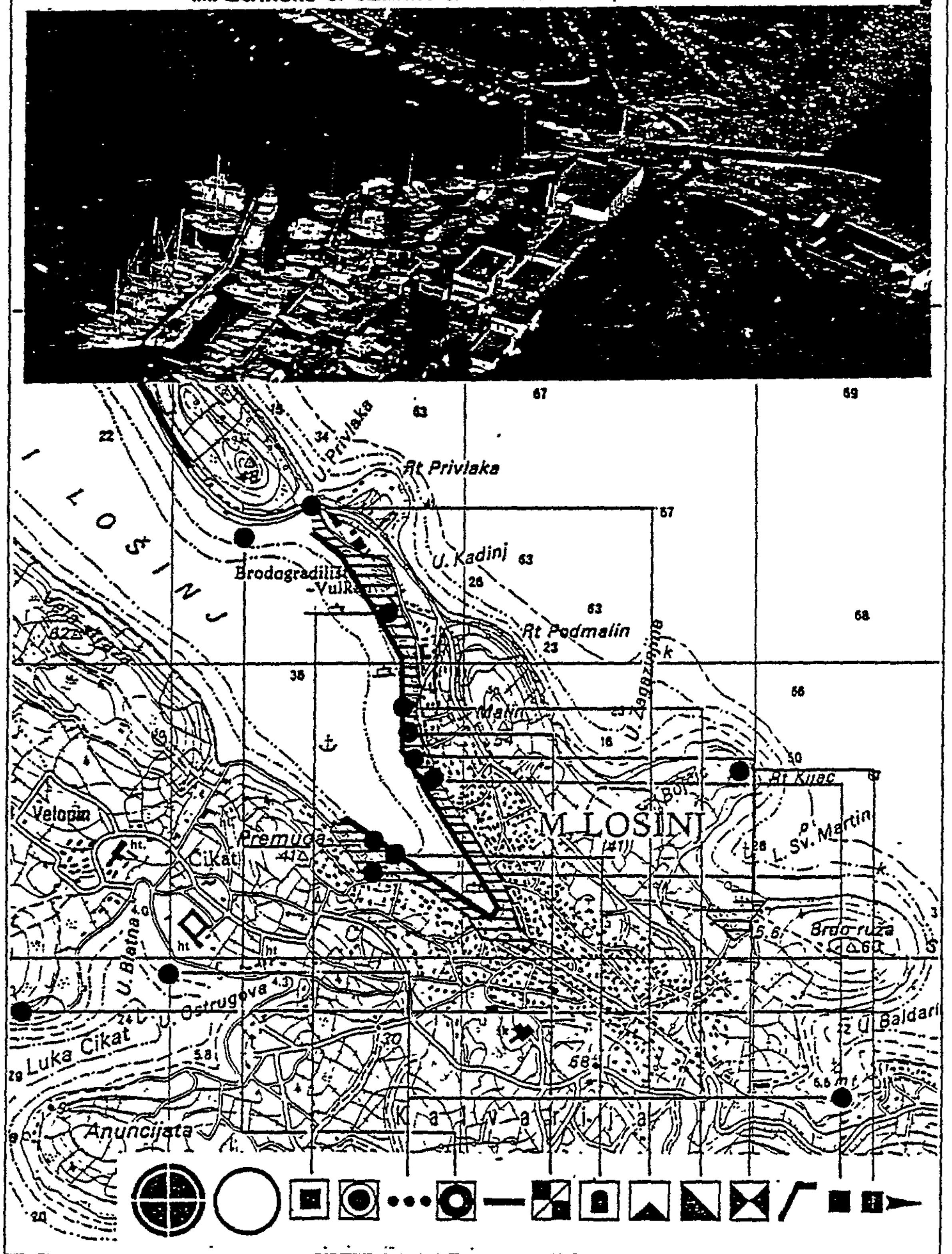

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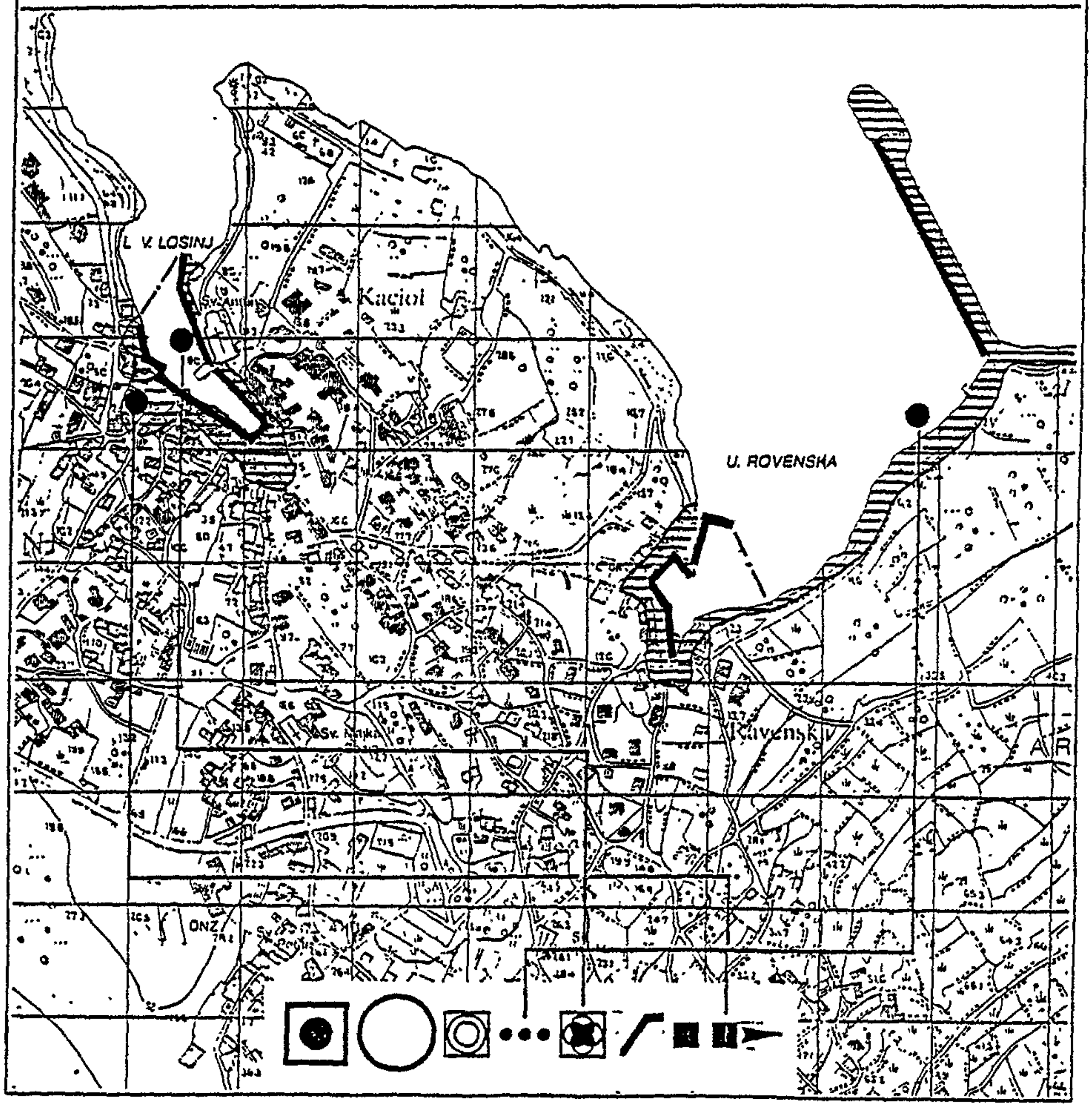

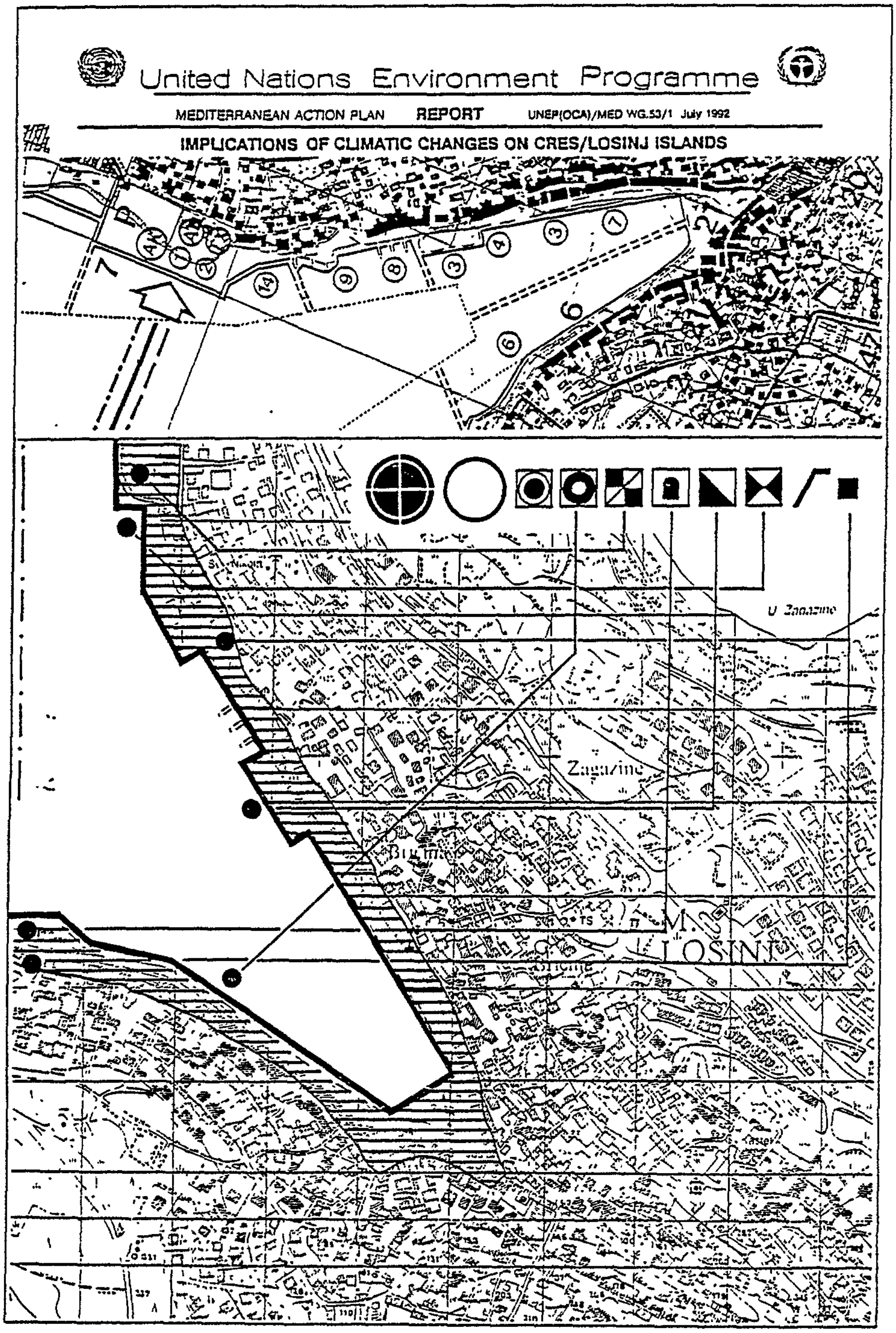
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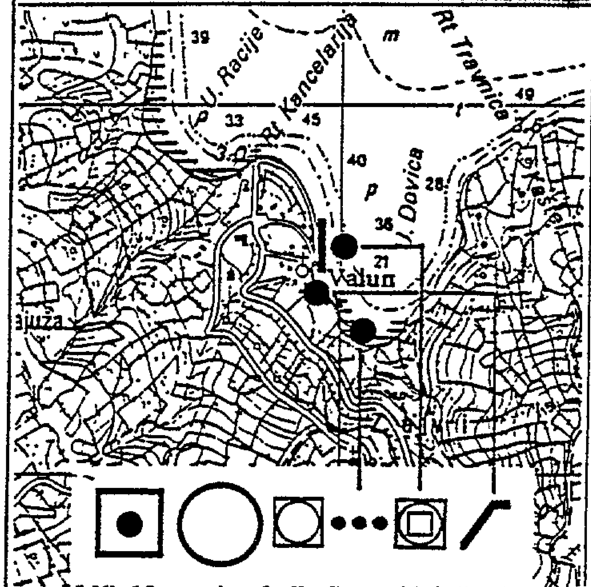

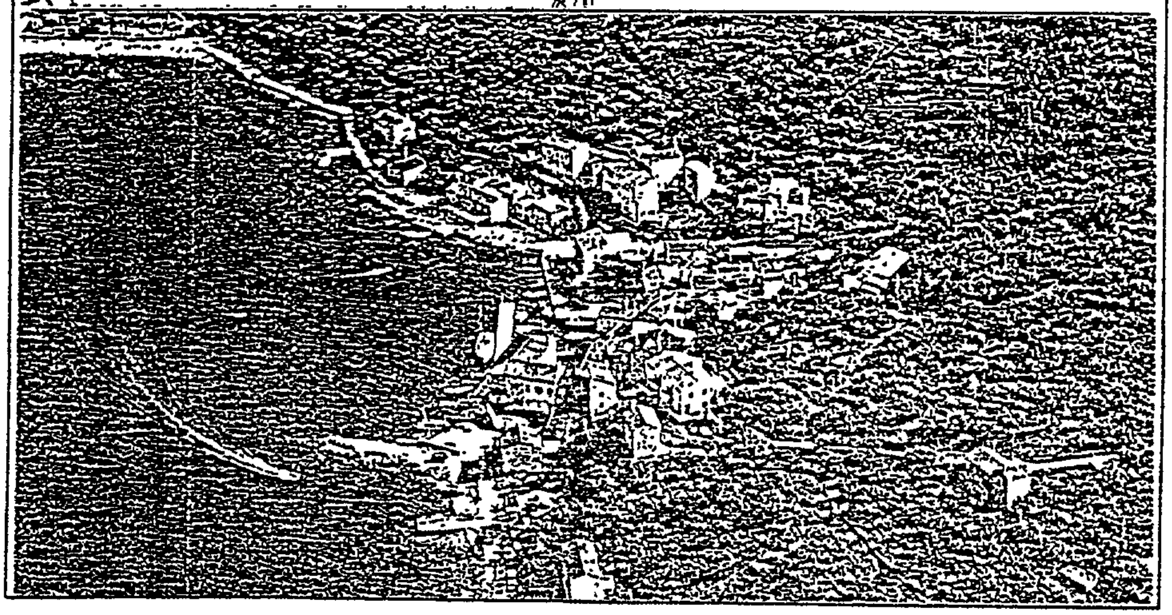

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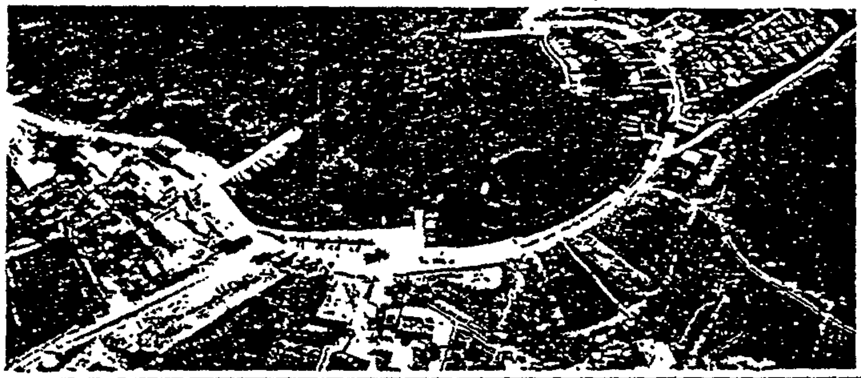

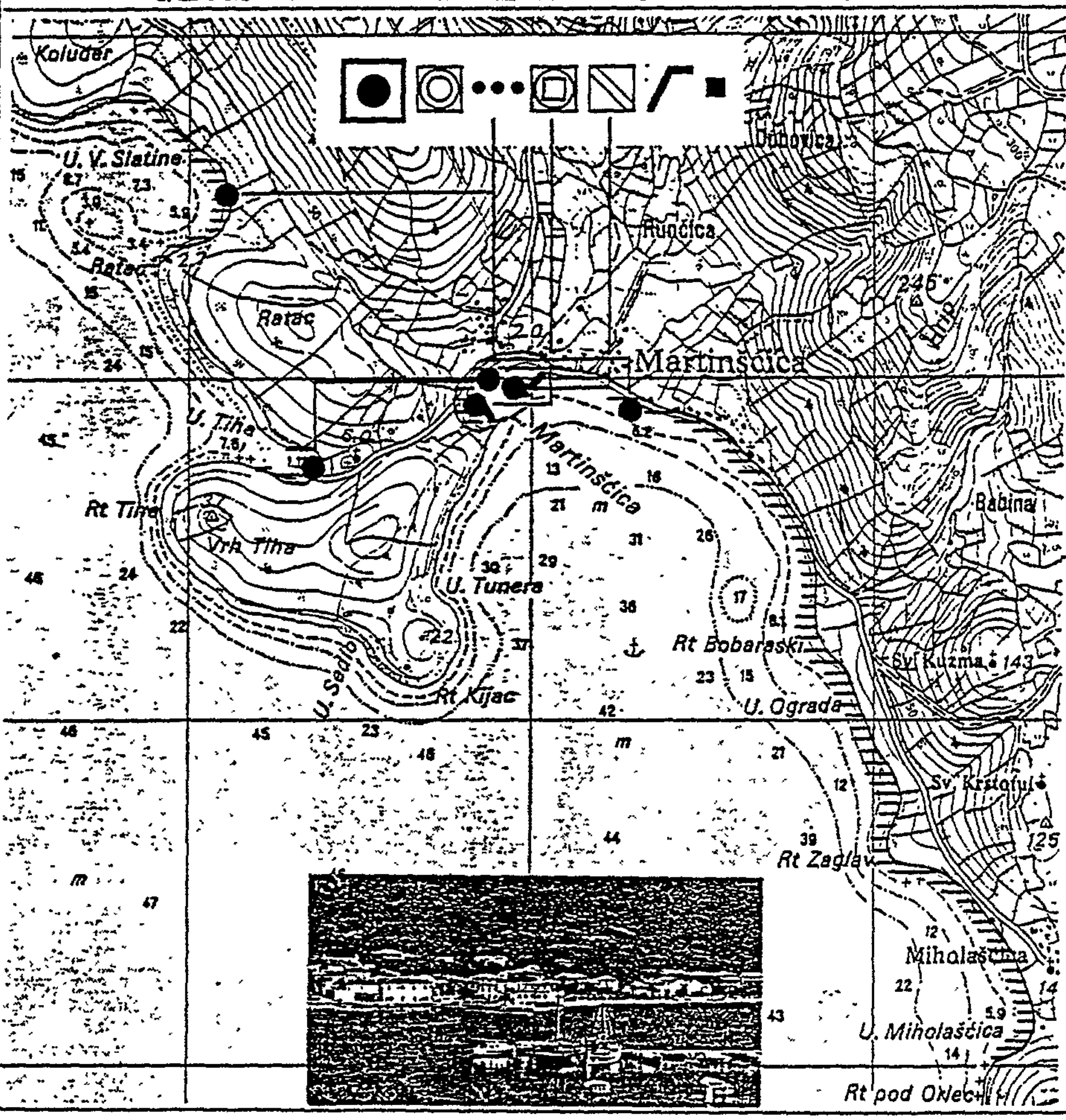

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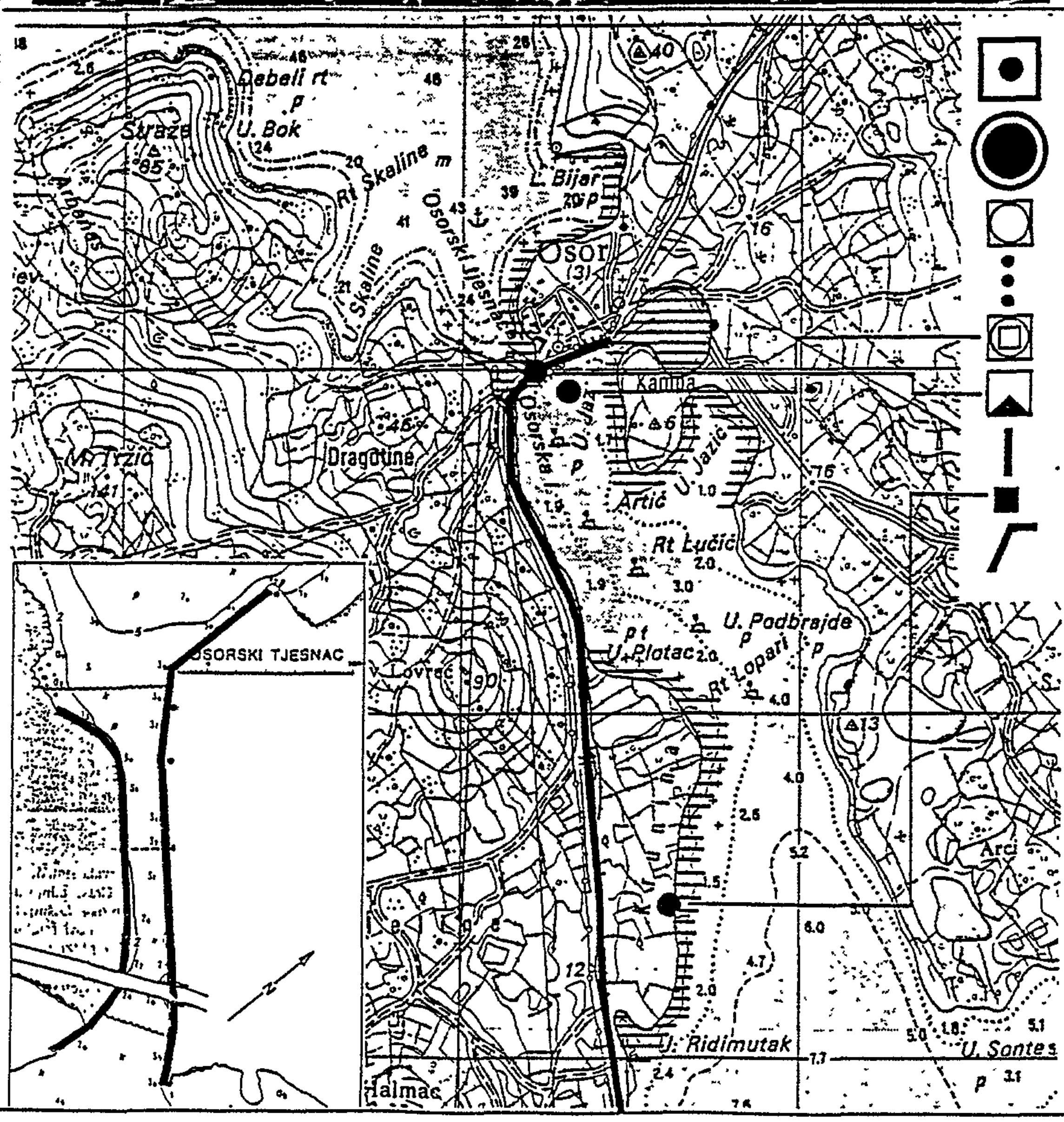

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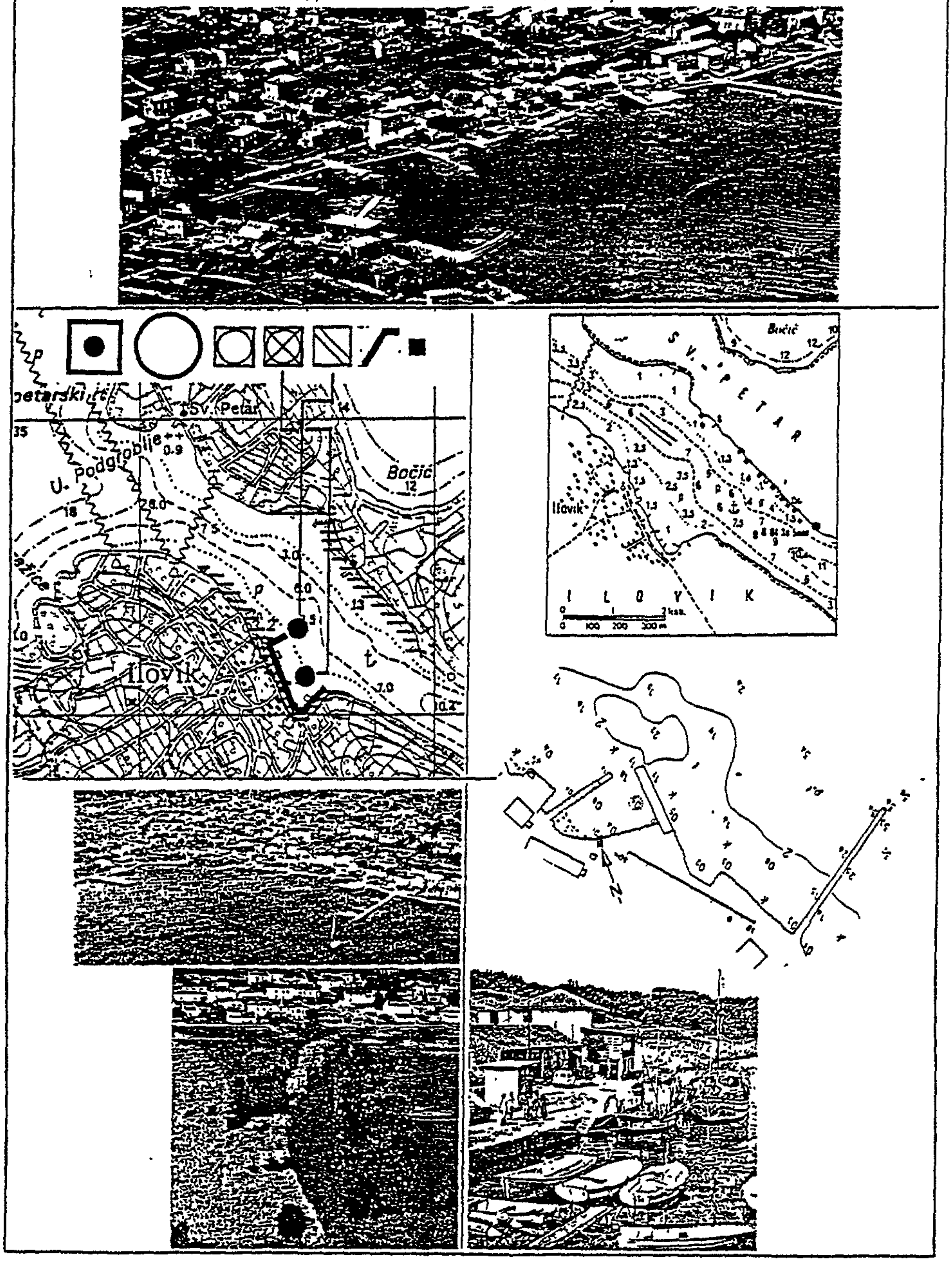

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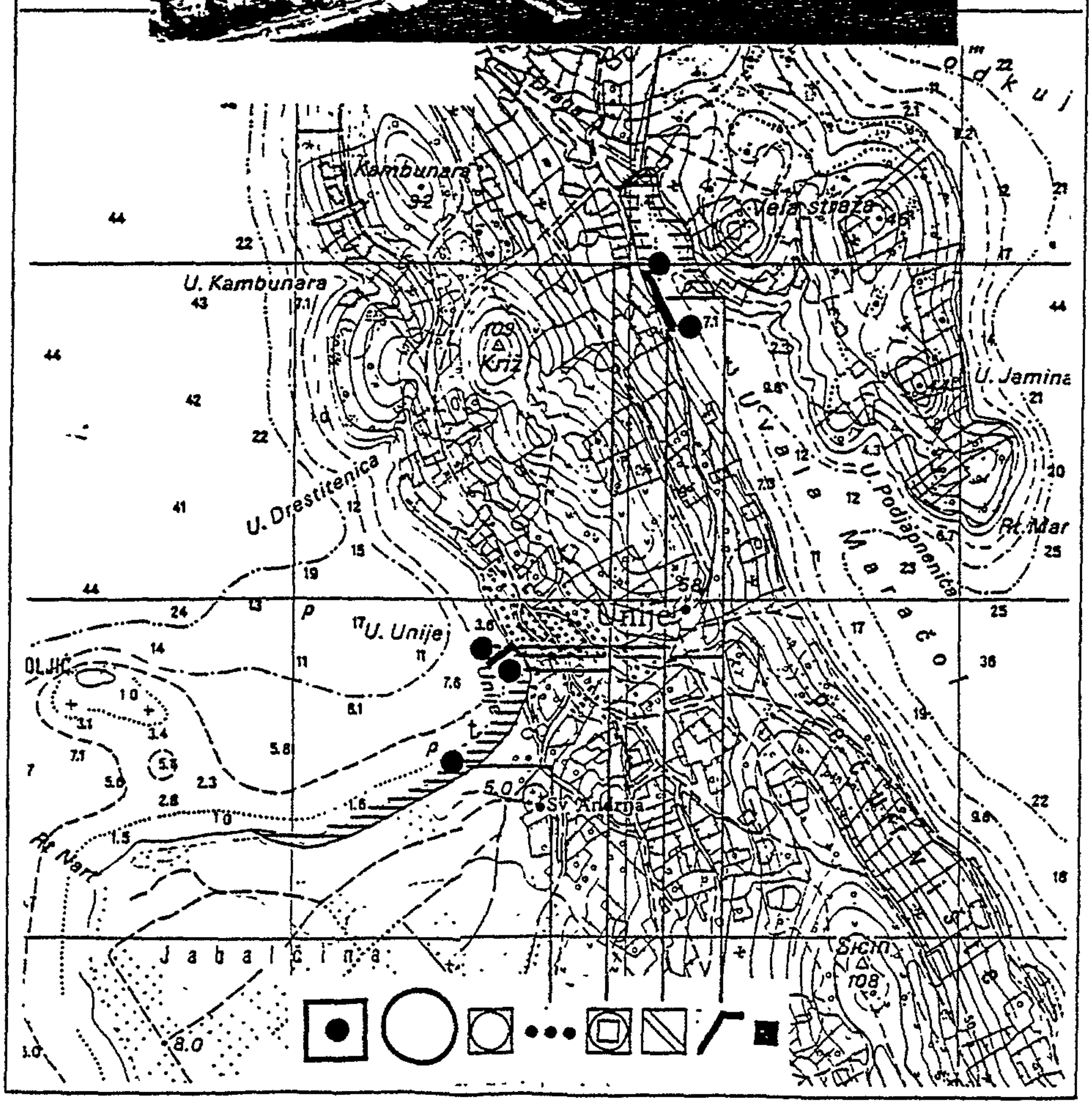

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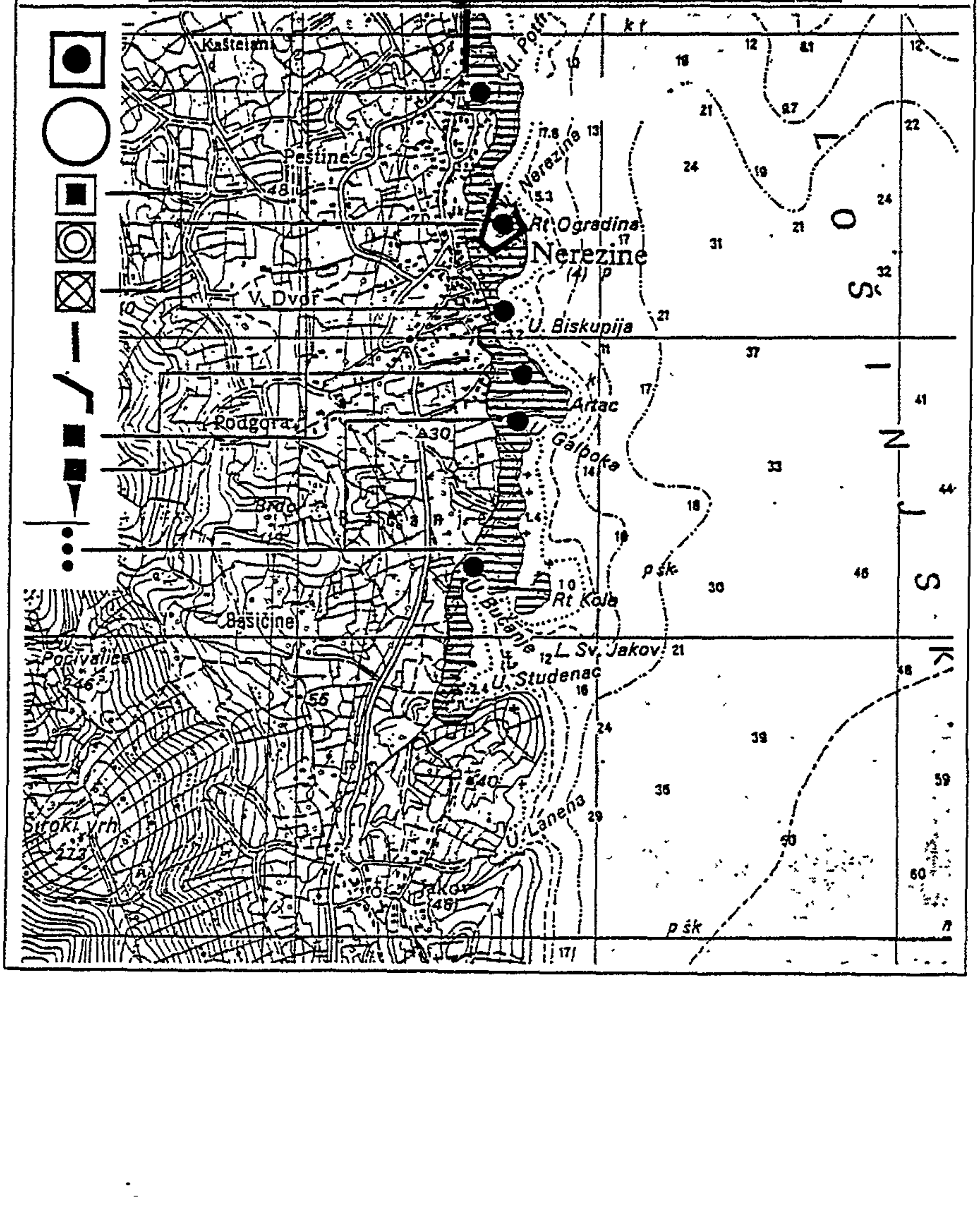

3. SYNTHESIS OF FINDINGS

3.1. Present Situation

On the basis of the analysis carried out within the substantive sections of the study, the synthesis of findings of present situation is made up.

3.1.1 Climate Conditions

The Cres-Losinj archipelago has maritime climate, with rather warm summers and no cold winters. The average temperature in the warmest month is 22 °C (July) an in the coldest 6-8 °C (January). The prevailing winds are bora and scirocco. The maximum of precipitation occurs in autumn and the minimum in summer, with the respective seasonal averages of 300-350 and 150-200 mm.

Since 1890 there was no significant trend in temperature (annual average 12-15 °C) and precipitation (annual average 900-1500 mm) for the Cres-Losinj archipelago, although the precipitation was slightly decreasing at Crikvenica (nearby but not within the archipelago) in the same period.

3.1.2 Lithosphere

The islands of the Cres-Losinj archipelago are predominantly built of limestone and dolomite, and that gives them the major morphological characteristics. The coastal areas are in general stable, with the exception of the western parts of Cres island which is built of flish sediments subject to erosion. The aeolic sediments on the islands of Unije and Susak are exposed to erosion, as well as the low-lying coastal zones (e.g. at Punta Kriza, Osor, Cres, Valun, Mali Losinj), which are even at present sometimes under the attack of sea.

3.1.3 Hydrosphere

There are no significant surface streams on the archipelago. The few coastal and submarine springs have no value for the development of the islands' freshwater supplies.

Lake Vrana on the island of Cres is the only supply of fresh water for the archipelago. It has a surface of 5 km^2, and a volume of about 220 million m^3. The surface of the lake is about 10 m above the sea level, the deepest point is about 65 m below the sea level. At present it supplies annually about 2.2 million m^3 (140 litres per second maximally) of fresh water; the planned maximal discharge is 306 litres per second. The salinity of the lake water is between 60 and 70 mg per litre. In the last ten years the water level was low and showed a decreasing tendency. During the same period the precipitation over the lake was decreasing, while the temperature had an increasing trend.

3.1.4 Atmosphere

On the archipelago there are no significant sources of pollutants carried by air; they mostly originate from the emissions in the Kvarner Bay.

During the period 1986-1989 data were collected at Veli Losinj on daily mean SO_2 concentration, precipitation acidity (Ph), prevailing weather types and the number of meteorological parameters (temperature, wind, precipitation, insolation, cloudiness). The data and observations revealed that higher levels of air pollution are generally more frequent in autumn and winter when cyclonic activities with stronger southerly winds, and anticyclonal conditions with northerly winds are frequent. The recorded SO_2 concentrations were ranging from 6 ug per m^3 in summer to 27 in winter. Higher levels (the 95 percentile value was 40 ug per m^3) and episodes (up to 190 ug per m^3) are predominantly associated with northerly winds when transport from Kvarner Bay dominates. Half of precipitation Ph values were within the range of 4 to 5, particularly in autumn and winter.

3.1.5 Natural Ecosystems Including Specially Protected Areas

3.1.5.1 Terrestrial Ecosystems

In the past the archipelago was covered by two types of climazonal forests: the Eu-Mediterranean forest of evergreen oak, and the sub-Mediterranean deciduous forest. Large parts of the these natural forests had been changed by human activities and turned into pastures of grassland and agricultural land. The animal component, especially the predators (mammals), became scarce. However, bird populations are still present, almost unchanged.

There are two separate specially protected areas at the eastern coast of the island Cres, Both of them are protected as ornithological reserves because they are nesting grounds of vultures.

Five zones are recognized as important from the standpoint of nature protection and will be proposed to be protected as specially protected landscapes. The small island of Veli Osir and forest Niska at Tramontana will be proposed to be protected as botanical reserve. The area of Lake Vrana will be proposed to be protected as graphical and hydrological reserve. The pine forest in the Cikat will be proposed to be protected as park forest.

3.1.5.2 Freshwater Ecosystem

The freshwater ecosystem is closely connected with the hydrosphere of Lake Vrana described in section 2.3. The ecosystem is under special protection covering the whole lake area, which forbids any activity not connected with the use of the lake as source of water supply for the archipelago. It consists of elements typical for freshwater lakes with stable temperature and hydrochemistry below the depth of 20 m.

3.1.5.3 Marine Ecosystems

The marine environment around the Cres-Losinj archipelago is typically oligotrophic. It is characterized by high salinity (36.5 - 38.5 x 10-3) surface temperature fluctuations (10 - 24 °C), low primary productivity, and variety of marine organisms. Nanoplankton (< 20 um) is dominating throughout the year, except during diatom blooms in autumn and late winter. Small blue fish, white fish and scampi are the most important commercially exploited species.

The area is under the influence of meteorological, oceanographic and hydrological changes occurring in a much larger region, The hydrographic and biological properties of the whole area are under the influence of the central Adriatic during most of the year, although during summer water exchanged with northern Adriatic may play substantial role. Aside from the waters around the northern parts of Cres Island, which are affected by the freshwater discharges in the Kvarner region, there is no major local influence on the ecosystem.

Sea currents have a northward direction throughout the year, with the exception in Rijeka Bay and Kvarner during summer, when currents from opposite direction prevail. Due to temperature gradients strong thermocline is established during summer in the whole area. Waves forced by southern winds can occasionally reach a height of up to 3 m.

Since 1956 relative sea-level increase is observed (about 0.5 mm per year).

3.1.6 Managed Ecosystems

3.1.6.1 Agriculture

The island of Cres and Losinj have about 600 hectares suitable for intensive agricultural production, but today only about 25 per cent of that surface is used. Additional areas suitable for agriculture are too fragmented and inaccessible for mechanization, thus suitable only for extensive agriculture requiring considerable labour. Olive growing (about 120,000 trees) and sheep breeding (about 25,000 sheep) is practiced on about 13,500 hectares. Both of these activities have an uncertain future. Vegetables are produced on a smaller scale around the towns of Cres and Veli Losinj. On the island of Unije about 80 hectares are under wheat and on the island of Susak there are about 10 hectares of vineyards.

During the last 50 years agriculture and sheep breeding showed a decreasing trend, due to depopulation of the island and orientation towards tourism and maritime activities. A number of vineyards and olive plantations were abandoned, and pastures turned into macchia.

3.1.6.2 Fisheries

In the past, fishing was one of the principal activity of the local population and fish was a very common food. At present the number of people involved in fisheries is much smaller but they catch more fish for commercial purposes.

There is no change in the total catch of small blue fish (sardines), cephalopods and scampi. The catches of bigger blue fish (e.g. mackerel and tuna) are decreasing for reasons which are not clear. The catches of white bottom fish (e.g. *scorpaena, sparus, corvina, dentex, chrysophrys, gadus, merluccius*) are decreasing and some species are close to be over-fished.

About 150 bigger and 400 smaller fishing boats operate in the area of the archipelago. According to a rough estimate (fisheries statistics are quite inaccurate), The annual catch is about 1500 tons of blue fish and 800 tons of white fish.

3.1.6.3 Aquaculture

At the turn of the century some shellfish culture were introduced in the Cres-Losinj area (up to 100.000 oysters were annually produced in Cres), but the cultures were discontinued before 1914. Presently no aquaculture is practiced on the archipelago, although the revitalization of this activity is envisaged by long-term development plans.

3.1.6.4 Sylviculture

The forest cover to the archipelago is represented by two climazonal associations. The northern part of the Cres Island, northward from the Sv. Bla' - Merag line, is covered by the deciduous forest. Southward from that line the archipelago is covered by evergreen oak forests. The latter was removed at the higher rate than the deciduous forests, and converted into pastures ar agricultural land. At present 62 per cent of the Cres and Losinj islands surface is covered by forests; about one third of the forests are in private property.

3.1.7 Energy and Industry

Industries in the commune of Cres-Losinj include three shipyards (1.5 m above sea level), a fish canning factory (at sea level), seasonal olive oil production, textile factory, two marinas, and two petrol stations in the coastal area (one at sea level).

Electrical power, supplied from mainland through an underwater cable is the main source of the energy on the archipelago. The present requirements of the archipelago are 15 MW; the requirements for the year 2015 are estimated as 75 MW.

3.1.8 Tourism

Tourism in many diverse forms is one of the most important economic activity of the archipelago. It is strongly dependent on factors, such as climate, vegetation, water supply, historic sites, links with the mainland.

The total bearing capacity of the archipelago is about 36,000 tourist beds of which more than half are in camps. Most of them are around the cities of Cres, Osor, Mali and Veli Losinj which are valuable historic cities.

3.1.9 Transport and Services

Maritime transport by ferries is the most important means of transport, enabling the connections with the mainland and between the small islands of the archipelago. There are 13 ports and ferry terminals for ships of local and long distance lines.

The main feature of the road network on the islands is an six metre wide spine road that starts from Porozina and Merag in the north and extend southward past the town Cres to Osor where it crosses the bridge to Losinj. The road continues from Osor southward to Nerezine and Mali Losinj ending. At Veli Losinj most of the important villages are served by minor roads leading from it.

The network of roads is of relatively standard. There are two draw-bridges on the archipelago at narrow sea channels (Osor, Mali Losinj).

On the island of Losinj there is an airport for smaller airplanes.

The telecommunication network is of good quality and coves the whole archipelago.

3.1.10 Health and Sanitation

The main health problems in the Cres-Losinj archipelago are similar to those in Croatia as a whole, namely: respiratory infections; nervous disorders; disorders of the heart and circulatory system and urinary organs.

The water supply system of the Cres-Losinj municipality derives its potable water from the Vrana Lake. The current demand is approximately 70 litres per second, reaching 150 litres per second during the summer season. The maximum supply capacity of the lake has been estimated at around 300 litres per second throughout the year. The existing system supplies the town of Cres to the north and as far south as Mali and Veli Losinj.

Only a small part of the islands is covered with a sewerage system which is mostly combined with storm water disposal and is in a bad condition. There is a sewerage system with preliminary treatment and submarine outfall 800 metres in length at Veli Losinj. Other places have temporary, short outfalls without treatment. The sewerage system in some coastal areas is already exposed to flooding and seawater penetrates the system. Coastal water pollution results from the direct discharge of untreated wastes.

There are two land fills in commune; one is situated about five kilometres from Cres and the other is near Losinj. About 50 per cent of communal solid waste is disposed of on these land fill sites and the rest on uncontrolled sites.

3.1.11 Population and Settlement Pattern

In 1991 the archipelago was inhabited by 11,639 people, living in 39 settlements. Twelve of these settlements,,with 90 per cent of the archipelago's total population, are in the coastal belt. Mali and Veli Losinj (7,500 inhabitants) and Cres (2,200 inhabitants), both on the coast, are the largest settlements.

There is a constant trend in migration: within the archipelago from smaller to bigger settlements; and from the mainland to the coastal settlements of the archipelago.

3.2 Major Expected Changes and Their Impacts

3.2.1 Climate Conditions

In addition to the expected increase in mean temperature by several degrees, a change in extremes can also expected. The precipitation is expected by several per cent to be higher in winter and somewhat lower in summer than present.

Changes in atmospheric circulation may occur they could influence a redistribution of atmospheric systems in time and space, causing changes in wind intensity as well as in some other weather parameters (e.g. cloudiness, insolation). Precipitation extremes may become higher if convective precipitation would prevail.

Some subtropical climate characteristics will move northwards.

Scenario for predicted climate change in the Cres-Losinj archipelago deduced from scenarios by IPCC and the University of East Anglia adapting the following figures:

- Losinj	2030 AD	- temperature	+1.6 to +1.8 °C
		- precipitation	0 to -5%
	2050 AD	- temperature	+1.4 to +2.8 °C
		- precipitation	0 to -9%
	2100 AD	- temperature	+1.8 to +5 °C
		- precipitation	0 to -15%
- Cres	2030 AD	- temperature	+1.8 to +2.0 °C
		- precipitation	0 to 5%
	2050 AD	- temperature	+1.5 to +3.3 °C
		- precipitation	0 to 9%
	2100 AD	- temperature	+2 to 5.5 °C
		- precipitation	0 to +15%
- sea level rise	2030 AD		+18 +/- 12 cm
	2050 AD		+38 +/- 14 cm
	2100 AD		+65 +/- 35 cm

3.2.2 Lithosphere

Although less than 1 per cent of the total area of the archipelago is endangered by the predicted sea-level rise, some problems can be expected in the low-lying coastal zones which could be permanently flooded in the second half of the next century. Stronger erosion could be expected in these zones which may particularly affect urbanized areas. The flish sediments in the coastal areas between Lubenica and Martinsjica may experience landslides. Similar phenomena may occur on the islands of Unije, Susak and Srakane.

Temperature elevations combined with decreased precipitation may lead to erosion of the topsoil, which is relatively thin and without contact with very deep groundwater reservoirs.

3.2.3 Hydrosphere

Increasing evaporation trend and further decrease in the level of the Vrana lake could be expected. There is a possibility that the Vrana lake may not be able to satisfy the freshwater supply requirements of the Cres-Losinj islands.

The possible influence caused by extent of snow cover and the dynamics of its melting on the catchment basin of the Vrana Lake could be expected.

3.2.4 Atmosphere

The predicted changes in temperature, precipitation and frequency of extreme events, might enhanced the air pollution in the area related to the emissions from the whole Kvarner Bay. Due to temperature rise, orographically induced effects and local circulation in the Kvarner Bay could intensify, and stronger northerly winds might be more frequent, causing the transport of pollutants towards the Cres-Losinj archipelago.

Changes which may occur in the air circulation over the western Mediterranean region could also affect the levels of air pollution in the archipelago and the processes related to it (e.g. transformation of pollutants, chemical reactions, wet and dry deposition). However, since the present concentrations of SO_2 are generally low (on average about 15 ug per m^3) significant changes are not to be expected, although extreme events might be more frequent.

Increase in the winter precipitation might lead to stronger acidification of soils and vegetation.

3.2.5 Natural Ecosystems Including Specially Protected Areas

3.2.5.1 Terrestrial Ecosystems

Expected effects, and most vulnerable systems and activities

The predicted climate change may affect the natural forests, primarily in the contact zones between the two main types of forests. The areas covered by sub-Mediterranean forests may be expanding at expense Eu-Mediterranean forests, and may be loosing sub-Mediterranean elements form their lower zones. For example, chestnuts on the northern part of cres are on the limit of their natural area, and may disappear altogether from the archipelago.

Effects on animal life, as well within the already protected areas, are not expected.

3.2.5.2 Freshwater Ecosystems

No changes in the temperature of Lake Vrana are expected because it is believed to be connected with deep groundwater. However, sea level rise might influence the level of the lake's salinity and thus affect its ecosystem and the use of the lake as water supply for the archipelago.

3.2.5.3 Marine Ecosystems

Temperature elevations will increase the temperature differences in the column of sea water and thus make it more stable (less vertical mixing). The stability could be further enhanced by the input of surface freshwater. However, the predicted higher wind frequency and intensity may act as a destabilizing force.

Higher seawater temperatures and freshwater inputs will increase the primary productivity, with general benefits for the whole ecosystem. The possible negative consequence of increased productivity could be an increase in oxygen demand in the bottom layer, if the water exchange is reduced. This could affect the composition of the benthic community by favouring species with higher tolerance for the fluctuation of oxygen levels. The positive effects of increased primary production could be cancelled if the produced organic matter ends up in the form of mucus (resulting from excessive phytoplankton production) floating on the surface of the sea, or inedible parts of the foodweb. Such development would negatively affect the tourist industry of the area and, probably, the fisheries.

Due to the expected sea-level rise (24-52 cm by the year 2050 and 30-100 cm by the year 2100), and likely increase in wave heights, the wave zones will increase in height, causing flooding of low-lying coastal areas, interference with the functioning of sewerage systems, threat to coastal buildings, installations and infrastructures.

The residual currents will be most probably reduced due to the expected lower input of freshwater into the greater area, thus extending the frequency and intensity of the influence of northern Adriatic waters to the western maritime area of the Cres-Losinj archipelago, and diminishing the now predominant influence of the central Adriatic.

3.2.6 Managed Ecosystem

3.2.6.1 Agriculture

The predicted increase in dry periods might affect agriculture negatively. For example, the growing of olive trees is quite dependent on precipitation in the months when it is predicted to be decreased. Extensive sheep breeding is heavily dependent on availability of rains for grass-growing and to fill the natural and man-made watering places.

3.2.6.2 Fisheries

Elevated sea temperature may increase the productivity of the waters around the archipelago, and this may have a positive effect on fisheries.

3.2.6.3 Aquaculture

The expected climate change is not likely to affect substantially the mariculture potential of the area, because the fish species planned to be used are eurytherm and euryhaline, and thus easily adaptable to the predicted changes. The reduced water exchange in some areas which may be used for fish-farming might affect the productivity of this areas.

3.2.6.4 Sylviculture

Climate change will particularly affect the forests outside of their natural habitats (e.g. chestnuts because of decreased soil humidity). Elevated average temperature may lead to the expansion of evergreen oak forest and regression of the deciduous forests, resulting in more frequent forest fires. The planed pine forests will be also the higher risk from forest fires. Elevated temperature may favour the occurrence of insects which may cause illness to trees or damage to the forest cover.

3.2.7 Energy and Industry

Temperature elevation is not expected to have a significant effect on the operation of the present industries. The total annual requirement for electric energy will probably remain the same, but with some decrease in winter (less heating) and increase in summer (a more intensive use of air-conditioners).

Sea level changes will affect the fish canning factory, the shipyards, the petrol stations situated in the coastal areas.

3.2.8 Tourism

With the increase in temperature the tourist season is expected to be prolonged and the year-round tourism may become more prominent. The more frequent and intense climate extremes (winds, storm, waves) might increase the dangers associated with nautical tourism.

The predicted sea level rise will have the most important effect on tourism, as it will lead to erosion of beaches. With a few exceptions, sea level rise will not affect the buildings used for tourism.

Historic centres of coastal cities will suffer because they are situated in low lying areas near the sea. The most vulnerable places are in Cres, Mali Losinj, Veli Losinj, Osor and Susak.

3.2.9 Transport and Services

The expected increase in frequency and intensity of winds and waves will have a negative effect on maritime transport. The number of days when some or even all ships and ferries will be unable to operate will probably increase. With the exception of new ports in Mali Losinj and Merag, all other harbours (length of 7,400 m) will be affected by sea level rise.

Sea level rise will also affect some parts of the road network (about 5 km), and the two bridges across the sea channels (Osor, Mali Losinj).

The airport is at 20 m above sea level and today it is extremely favorable microclimatic conditions. Therefore, it is not likely to be significantly affected by the expected climate change.

3.2.10 Health and Sanitation

In addition to the existing medical problems, the incidence of malignant neoplasms, cases of heat stroke and eye disease are all expected to increase under predicted climatic changes, placing an additional burden on health services in the Cres-Losinj archipelago. Extreme climatic conditions, exacerbated by increased air pollution, will cause an increase in heat stroke and respiratory problems (e.g. bronchial asthma, chronic bronchitis), particularly in children and elderly risk-group patients. In summer an increase in flies and mosquitoes could be expected. There might be also an increase in insect vectors which could cause an increase in virus-related illnesses, such as tick-borne encephalitis and papatachi fever. Stronger ultra-violet radiation may increase skin cancers and sight disorders, such as cataract.

Climate changes will cause flooding of the water supply network in the coastal areas as well as of the main distribution points. Corrosion effects are expected in the water supply installations while the rise of the sea level will cause a rise in the water level in wells located in the lower parts of the island, and will increase the salinity of this water. Lower rainfall in summer will cause water shortages in areas presently supplied by wells.

The rise of sea-level will also cause problems in the existing coastal sewage network. The increased rainfall (about 15 per cent in spring ba 2050) will cause problems of excess water in combined sewage and stormwater systems. The direct impact will be to increase pumping costs and pollution of the sea caused by dilution of the waste waters. Flooding effects are expected in coastal areas on the unregulated solid waste disposal sites. The erosion of the topsoil which is already relatively thin, will cause problems for the future solid management system (landfill).

3.2.11 Population and Settlement Pattern

The predicted sea level rise will be the most important change felt by the settlements on the coast. It is estimated that seven settlements (central parts of Cres, Mali and Veli Losinj, Osor, Nerezine, Susak and Ilovik) will be particularly affected; the effect on five additional settlements might be of smaller consequences. About 35 hectares of urban area, carrying about 600 buildings and housing about 13 per cent of the archipelago's present population, will be affected in these twelve settlements.

4. RECOMMENDATIONS FOR ACTION

4.1 Preventative Policies and Measures

According to the evaluation of the climate change impacts, certain actions are to be established in order to avoid or mitigate the negative effects resulting from them.

1. Assuming that climate change implications on the Cres-Losinj archipelago will manifest within the frame of global model, taking a gradual course, and without significant difficulties and consequences which cannot be put under control, yet it is very important already now to incorporate certain measures, suggested by the findings of this study, into the development policy of physical planning and environmental protection.

2. Since the climate change implications reflect gradually, special intervention and measures do not have to be taken at present, but every reconstruction or new building should pay due consideration to that impacts, especially in the connection with transportation, bank reconstruction regarding ports and marinas, as well as industrial facilities situated in the immediate coastal area.

Cost-benefit analysis, as a part of specific Environmental Impact assessment, should be carried out before reproaching to any significant investment or reconstruction.

3. Climate change consequences are strongly connected to and dependent on development concept of every area, so as for the Cres-Losinj archipelago, too. Development policy should be based on the principle of integral approach to planning and management activities, including social and economic development planning, physical planning and land-use/environmental management. Disregarding the fact that more significant negative impacts of climate might happen no sooner than in the second half of 21st century, an accelerated development and population increase might suffer the consequences caused by climate change

even before that time, especially this one regarding water shortage. The plan should incorporate special concern about water resources management (including the Vrana Lake as well as mainland and submarine wells, and collecting the water in wells, small accumulations and watering places). Considering that context re-use of waters becomes essential.

Recently completed Physical Plan of the commune of Cres-Losinj (including the whole archipelago) which comprises a lot of technical and socio-political elements being essential for integral approach in physical planning and environmental management, makes a good ground for incorporating possible recommendations and measures resulting from this study and which aim to alleviate the climate change impacts.

4. Since the climate impacts couldn't be considered as a local problem, and similar manifestations are expected on other Adriatic islands and coastal areas, certain recommendations resulting from this study could be foreseen for implementation on other islands with regard of avoiding sea level rise implications.

Therefore, it would be extremely useful after completing this Study, in the frame of UNEP, to continue at the national level, so as to make the judgements and selection of recommendations which could be taken into account for the whole coastal and island area of the Republic.

5. This Project should initiate further climate conditions monitoring as well as climate change impacts, with special regard to the natural ecosystems. This should be implemented on the whole coastal territory of the Republic of Croatia, emphasizing the elaboration of documentation on vulnerable zones, related problems and establishing of computerized data set system.

6. Policy and strategy concerning this subject should ensure the public participation and population of every age group, non governmental organizations as well as other social organizations and decision makes at political and economic level.

Therefore, it is of extreme importance to strengthen the information and educational system at all levels. All these activities should be organized in the sense of continual informing and warning, so as to provoke constructive reactions without turning into frightening methods.

4.2 ADAPTIVE POLICIES AND MEASURES

The problem of climate change is a global issue and effective responses would require a global effort.

The problem of global warming induced largely by anthropogenic makings in not purely technical question, it is in fact the problem with significant political and economic implications. The potentially serious consequences of climate change on the global environment give sufficient reason to begin by adapting strategies that can be justified immediately even in the face of significant uncertainties.

Short term measures are identified as applicable, which, while helping to tackle climate change, can yield other benefits.

The policy measures should be established at three main levels.

Information measures include the efforts to better inform the public on predictable problems and the means available to the public for their reduction. This include research, development and demonstration programmes for emerging technologies and education and training of professional experts in all sectors.

Economic measures include the broad areas of taxes, charges, subsidies, and pricing policies that include incorporating environmental costs into energy prices. These measures may also be used to support the research, development, demonstration, or application of technologies for enhanced energy efficiency or pollution control.

Regulatory measures include a broad array of control mechanisms, and standards regulations used for environmental protection have ranged from emission standards to requirements for environmental impact assessments.

Systems of the results obtained by sociological researches points out the following recommendations and suggestions:

- developing prevention and adaptation strategies to alleviate and avoid negative effects of expected global climate changes

- establishing of system of constant supervision (monitoring) of the status of the environment to enable timely prevention of possible negative consequences of expected climate changes whether on local or regional level

- organizing environmental management in cooperation with local inhabitants, local experts, as well as with foreign experts (experts on international programmes of environmental protection) who will be continually informing the local, state and international communities about changes in natural and social environment caused by changing of global climatic conditions

- starting a longitudinal sociological and related research programmes about adaptation of social and technological systems to changes resulting from changes in global climatic conditions.

ANNEX

TEMPERATURE AND PRECIPITATION SCENARIOS FOR THE NORTHERN ADRIATIC

Report to the UNEP Co-ordinating Unit for the
Mediterranean Action Plan

(in alphabetical order)
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April 1992

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SUMMARY

We have applied the methods developed by Kim et al. (1984) and Wigley et al. (1989) to the problem of constructing sub-grid scale climate change scenarios for the northern Adriatic. Regression equation were developed to predict station temperature and precipitation anomalies from regionally-averaged climate anomalies. We proceeded to substitute GCM perturbed-run minus control-run values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium temperature of each of the four GCMs and an average for the four models obtained. The procedure was repeated for every station in the data set, and the results contoured to produce a scenario for the northern Adriatic.

Annual and seasonal scenarios for both temperature and precipitation change were produced. For temperature, the same pattern of change is seen throughout the year, with a sensitivity greater than the global value in the north-east of the study region, and lower than the global value (i.e. less than 1 °C per °C global change) in the south-west and, to a lesser extent, the south.

The scenarios for precipitation are much more difficult to evaluate. At the annual level, there is a trend across the country from an increase in precipitation in the north-west to a decrease in the south-east. The estimated changes are in the range of 13 to -5% per °C global warming. This pattern is repeated in three seasons of the year: winter, spring and autumn. The smallest changes are suggested by the spring scenarios (a range of 17 to -1% per °C) and the largest in autumn (a range of 22 to -7% per °C). The summer pattern is rather different, with most of the region apart from the north-east displaying a decrease in rainfall. The problems associated with the construction of regional scenarios of precipitation change associated with the greenhouse effect are discussed at length in the Final Report for the UNEP Mediterranean Project. The confidence that we can place in sub-grid-scale scenarios of precipitation is low.

1. THE USE OF GCMS IN REGIONAL SCENARIO DEVELOPMENT

It is generally accepted that results from General Circulation Models (GCMs) offer the best potential for the development of regional climate scenarios. They are the only source of detailed information on future climates which can extrapolate beyond the limit of conditions which have occurred in the past.

GCMs are complex, computer-based, models of the atmospheric circulation which have been developed by climatologists from numerical meteorological forecasting models. The standard approach is to run the model with a nominal "pre-industrial" atmospheric CO_2 concentration (the control run) and then to rerun the model with doubled (or sometimes quadrupled) CO_2 (the perturbed run). In both, the models are allowed to reach equilibrium before the results are recorded. This type of model application is therefore known as an equilibrium response prediction.

The fact that the GCMs are run in equilibrium mode must in itself be regarded as a potential source of inaccuracy in model prediction. It can be argued that the predicted regional patterns of climate change will differ from those that will occur in a real, transient response world. This is because equilibrium results ignore important oceanic processes, not last ocean current changes, differential thermal inertia effects between land and ocean, and changes in the oceanic thermohaline circulation. Transient response predictions, where the CO_2 concentration increases gradually through the perturbed run and where the oceans are modelled using ocean GCMs, and which therefore should provide a more realistic estimate, are becoming available. However, the complexity of the problem in relation to present-day computing capability casts doubt on the reliability of the results, and this is likely to remain the case over the next decade. The present study restricts itself, therefore, to the use of results from equilibrium GCM experiments.

The results from four GCMs developed for climate studies are used in this report. These four are from the following research institutions:

UK Meteorological Office (UKMO)
Goddard Institute of Space Studies (GISS)
Geophysical Fluid Dynamics Laboratory (GFDL)
Oregon State University (OSU)

The models vary in the way in which they handle the physical equations describing atmospheric behavior. UKMO, GISS and OSU solve these in grid-point form whereas GFDL uses a spectral method. All models have a realistic land/ocean distribution and orography (within the constrains of model resolution); all have predicted sea ice and snow; clouds are calculated in each atmospheric layer in all models.

One problem with the application of GCMs to the study of climate impacts is the coarse resolution of the model grid. The grid scale of the four models listed above ranges from 4° latitude x 5° longitude (OSU) to 7.83° latitude x 10° longitude (GISS). GCMs, therefore, have a spatial resolution of several hundreds of kilometer, which is inadequate for many regional climate change studies, especially in areas of high relief. We present here a set of high resolution scenarios for the northern Adriatic, based on the statistical relationship between grid-point GCM data and observations from surface meteorological stations.

2. CONSTRUCTION OF SUB-GRID-SCALE SCENARIOS

Kim et al. (1984) looked at the statistical relationship between local and large-scale regionally-averaged values of meteorological variables: temperature and precipitation. They than used these relationships, developed using principal component analysis techniques, to look at the response of local temperature and precipitation to the predicted change at GCM grid points. The area of study was Oregon State. Although the paper contains certain statistical flaws, the underlying idea of relating local and large-scale data statistically is sound. The method of Kim et al. has been extended and refined by Wigley et al. (1990) and by Wilks (1989).

The methods of Kim et al. and Wigley et al. have been modified for application in the Mediterranean region. In the model validation exercise carried out for the Mediterranean Project (see Final Report) it was established that no single GCM can be identified as being always the best at simulating current climate. This being case, there is little merit in presenting scenarios based on only one model. Presentation of scenarios for each of the four models avoids the issue, since the task of deciding which model is "best", and/or of synthesizing the information to obtain a best estimate, is left to the impact analyst. We have therefore combined the information from the four models into a single scenario for each variable, according to the method described below.

The problem with presenting the scenarios in this form is that the results may be biassed by the different equilibrium responses of the individual models. The global warming due to $2xCO_2$ for the four GCMs ranges between 2.8 °C for the UKMO model run. We would therefore expect that the warming indicated by the UKMO GCM for the Mediterranean Basin will be greater than that suggested by the OSU model, even though the sensitivity of the region to climate change when compared to the global sensitivity might be the same. The individual model perturbations have therefore been standardized by the equilibrium (global annual) temperature change for that model, prior to the calculation of the four-model average.

We required a generalized computer program that would be applicable throughout this geographically complex area, and could be used with meteorological records of variable length and density. After investigating a number of approaches to the problem, we adopted the procedure summarized below:

1. Data sets of monthly mean temperature and total precipitation have been compiled for the area surrounding the Mediterranean Basin. Stations used in this study of the northern Adriatic are listed in Appendix 1. Where possible, each record should be complete for the period 1951-88. Any station with a record length less than 20 years in the period 1951-88 for over six months out of twelve was immediately discarded.

2. Then, for every valid station, the temperature and precipitation anomalies from the long-term (1951-88) mean were calculated. For this part of the work, which is the first step in the construction of the regression equations (the calibration stage), only the data for 1951-80 were used. The 1981-88 data were retained to test the performance of the regression models (the verification stage, see Final Report). For the calculation of the temperature anomaly At ij, the simple difference was used:

At ij = t ij - T j

where t ij is the mean temperature of month j in year i, and T j is the long-term mean for month j. The precipitation anomaly Ap ij was expressed as a ratio of the long-term mean:

Ap ij = (p ij - P j)/P j

where p ij is the monthly total precipitation in month j of year i, and P j is the long term mean for that month. If P j is less than 1 mm, then this equation is modified to:

Ap ij = (p ij - P j)/1.0

3. The individual station anomalies are used to calculate regionally-averaged anomalies. The procedures described from here to the end of Point 6 are station-specific, and must be repeated for each station in the data set.

A 5° latitude x 5° longitude square is centered over the station for which regression equations are to be developed (the predicted station). All the stations which fall within this square are used to calculate the regional averages. If the number of stations is less than three, for temperature, or four, for precipitation, the procedure is halted. For temperature, the anomalies from all stations in the 5° x 5° square are averaged month-by-month to produce an area-average time series. For precipitation, the substantial degree of spatial variability makes it advisable to area-weight the station anomalies before calculating the regional mean for each month. To do this, the 5° x 5° region is divided into 20 x 20 smaller squares. The precipitation anomaly value assigned to a particular square is that of the station nearest to it (with the restriction that the distance separating a square from its nearest station should be no greater than 1° - where the distance is greater the square is ignored). The area average is then the mean of the values in the 400 (or fewer, if any fail the minimum distance criterion) squares. This method is similar to the standard Thiessen polygon method.

4. Regression analyses were performed using station temperature and precipitation anomalies as the predictions. These analyses were carried out on an annual and seasonal basis: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October and November). By considering the monthly values as separate observations within each season, we were able to extended the number of observations and so preserve a high number of degrees of freedom. The predictor variables are the regionally-averaged anomalies of temperature and precipitation.

5. In order to determine the perturbation due to the greenhouse effect at each station, the results from GCMs were employed. It is assumed that a GCM grid-point temperature or precipitation value is equivalent to a regionally-average value derived from observational data. For each of the four GCMs (GFDL, GISS, OSU and UKMO), the perturbed run and control run grid-point temperature (t) and precipitation (p) values are interpolated to the station position. Then, we obtain, for temperature:

$$\text{Atm i} = \text{t i}(2 \times CO_2) - \text{t i}(1 \times CO_2)$$

where Atm is the perturbation due to CO_2 or the "temperature anomaly" for model i and, for precipitation:

$$\text{Ptm i} = (\text{p i}(2 \times CO_2) - \text{p i}(1 \times CO_2)) \times 100/\text{p i}(1 \times CO_2)$$

where Ptm is the standardized perturbation due to CO_2 or the "precipitation anomaly".

The values for Atm and Ptm foe each GCM are than substituted in the regression equations to obtain a prediction for the station perturbation of temperature (°C) and precipitation (%) due to CO_2.

6. The predicted change in temperature and precipitation for each model is divided by the equilibrium (global mean) temperature change for that model. The results are then averaged across the four models to obtain a composite value.

7. The procedures from Points 3 to 6 is repeated for each station Throughout the Mediterranean. The results can then be plotted and contoured to obtain a map of the expected patterns of temperature and precipitation change due to the greenhouse effect.

In order to arrive at this procedure, a rigorous investigation of the validity of the method has been carried out. In particular, we have looked at:

- the use other predictor variables in the regression equations

- performance and verification of the regression equations

- autocorrelation in the data

- multicollinearity in the predictor variables

These aspects are discussed in detail in the Final Report.

3. CLIMATE CHANGE SCENARIOS FOR THE NORTHERN ADRIATIC

The sub-grid-scale scenarios, constructed according to the method outline in Section 2, are shown in Figs. 1-5. The temperature perturbations are presented as the model average change, in degrees Celsius, per °C global annual change. The precipitation perturbations are shown as the percentage change for each 1 °C global annual change. This procedure is described in greater detail, and the approach justified, in Section 2.

The problem with expressing the scenarios in this form is then to scale the values up (or down) in relation to some realistic estimate of the temperature perturbation to be expected from the greenhouse effect. The IPCC Report (Houghton et al., 1990) provides one such family of estimates. For their Business-as-Usual scenario of emissions, the likely increase of global mean temperature by the year 2050 is predicted to be about 1 °C above the present level. By the end of next century, the increase is estimated at 3 °C above present-day. On this basis, the temperature and precipitation scenarios for the northern Adriatic presented in this report can be related directly to changes between now and the year 2050.

The scenarios for changes at the annual level are shown in Fig. 1. The temperature change in the northern part of the study region is estimated to be slightly above the global level, i.e. above 1 °C per °C global warming, whereas in the south it is shown to be slightly below. The pattern varies from as much as 1.5 °C per °C global warming in the north-east of the region, to only 0.9 °C per °C global change in the south. The change in precipitation is indicated as positive in most parts except for the south-east. In the extreme north-west, the change is as high as +13% per oC, but in the south-east the decrease in precipitation is shown to be around 3 to 5%.

In the winter months of December, January and February (Fig. 2) the predicted increases of temperature are 0.8-1.0 °C per °C global change in the south and north-west i.e. the same as, or slightly below, the global change. In the north-east, and along the coastal belt in the west, the suggested change is above the global level, rising as high as 1.6 °C per °C. The winter precipitation change map indicates an increase, rising as high as 21% per °C in the north-west, in most parts except for the extreme south and east of the study region.

Spring scenario temperature changes (Fig. 3) follow the same pattern as those indicated by the annual and winter scenarios: a trend of decreasing sensitivity to the greenhouse effect from north-east to south-west. Precipitation changes also follow the general annual and winter scenario pattern. There is a trend across the study region from increased precipitation in the north-west, to a slight decrease in the extreme south-east.

The temperature scenario for summer (June, July and August) is substantially different from the annual pattern shown in Fig. 1. It continues to follow the pattern of winter and spring, with the greatest changes (above the global level) in the smallest changes in the south-west. The precipitation scenario is, however, substantially different. A decrease in rainfall is predicted for most of the study region, apart from the inland area of the north-east. The decrease is high in percentage terms (up to 7% per °C) but in real terms is unlikely to be of significance due to the dryness of the season.

The range and pattern of autumn temperature changes, as indicated by the scenario of Fig.5, continues to follow the pattern that persisted in every season, and for the year as a whole. The precipitation trends also see reversion to those demonstrated by the winter and spring scenarios. Precipitation increases are greatest (over 12% per °C) in the north-west, and lowest in the south-east.

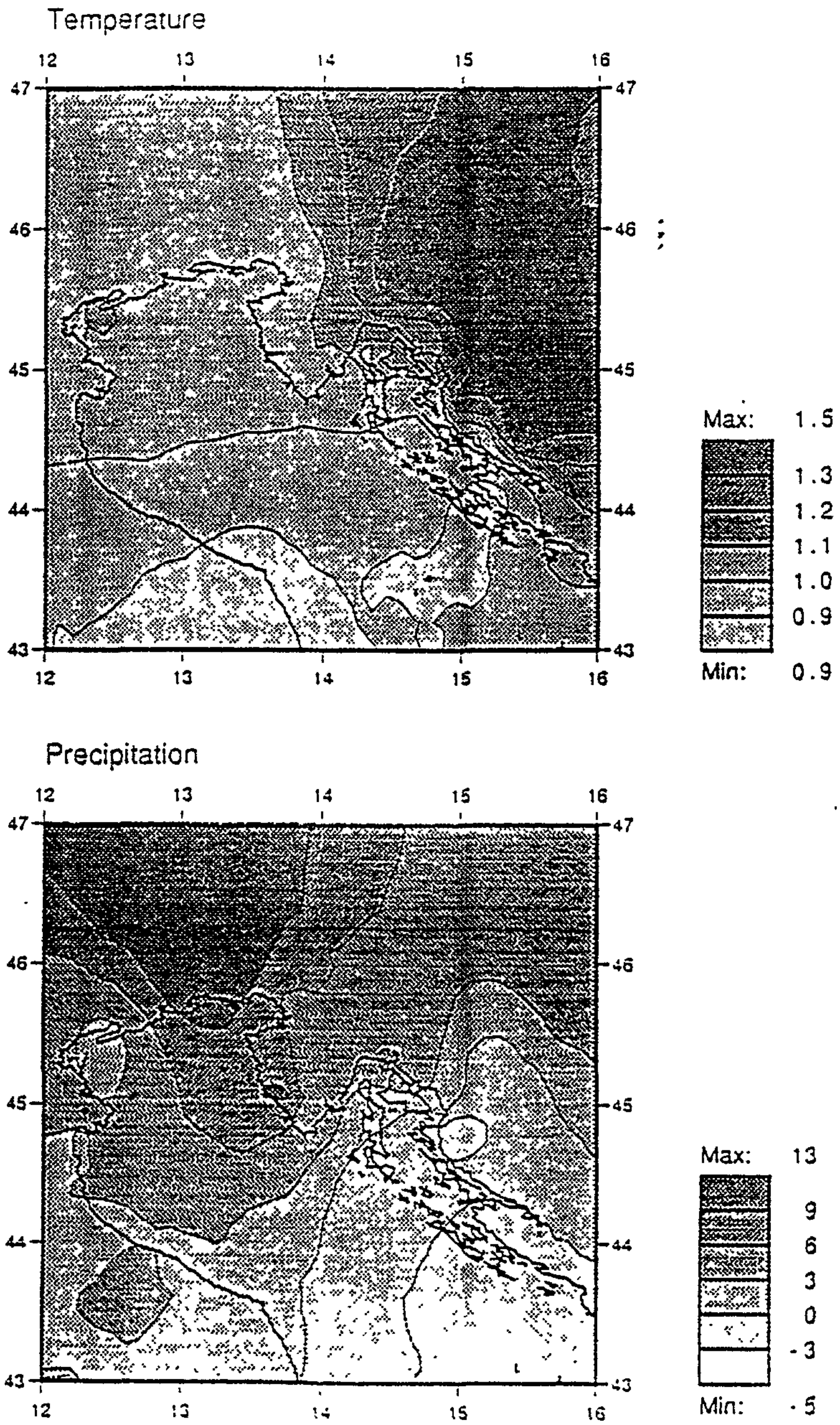

Figure 1 Regional climate scenarios for the northern Adriatic: Annual

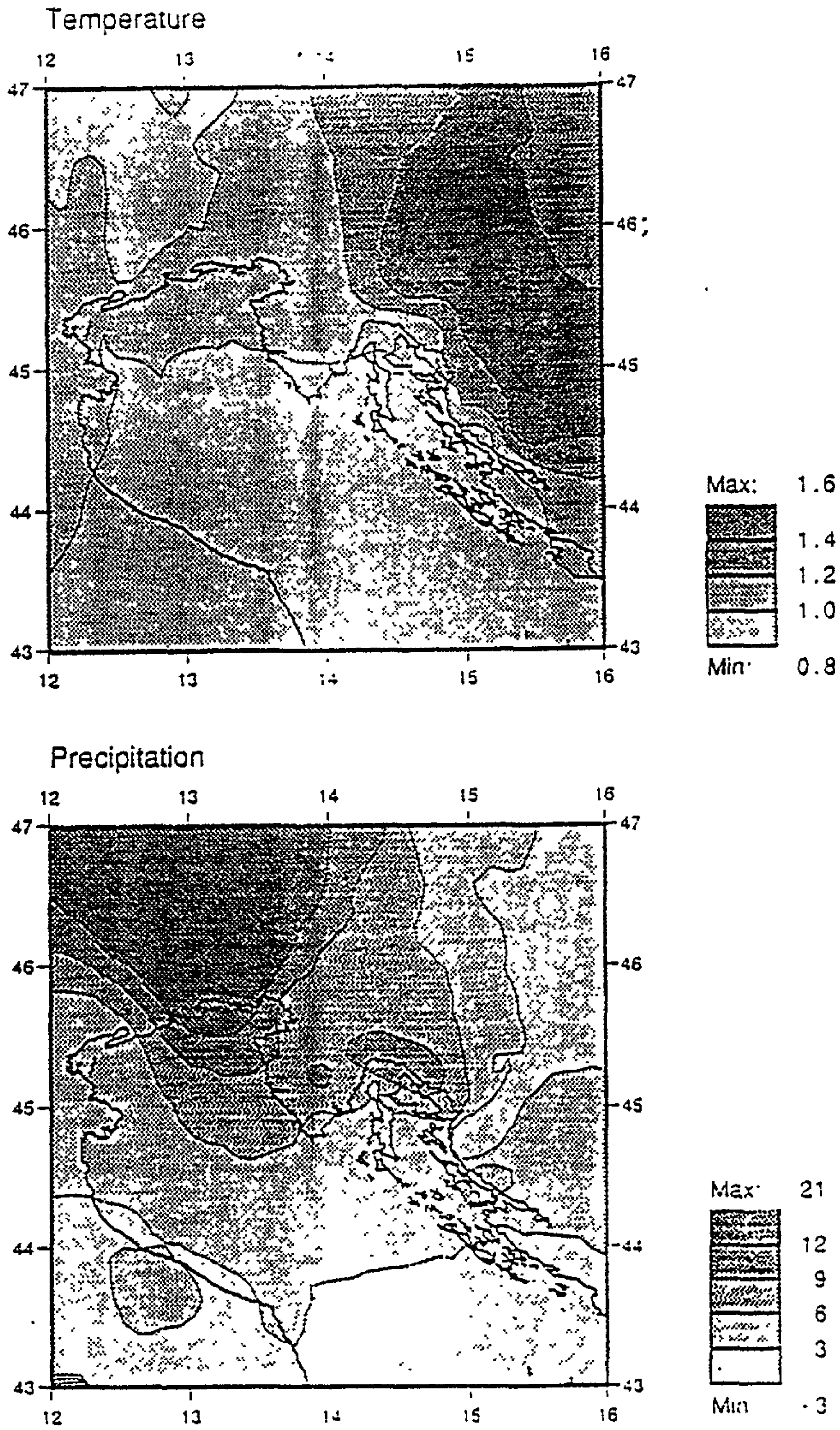

Figure 2 Regional climate scenarios for the northern Adriatic: Winter

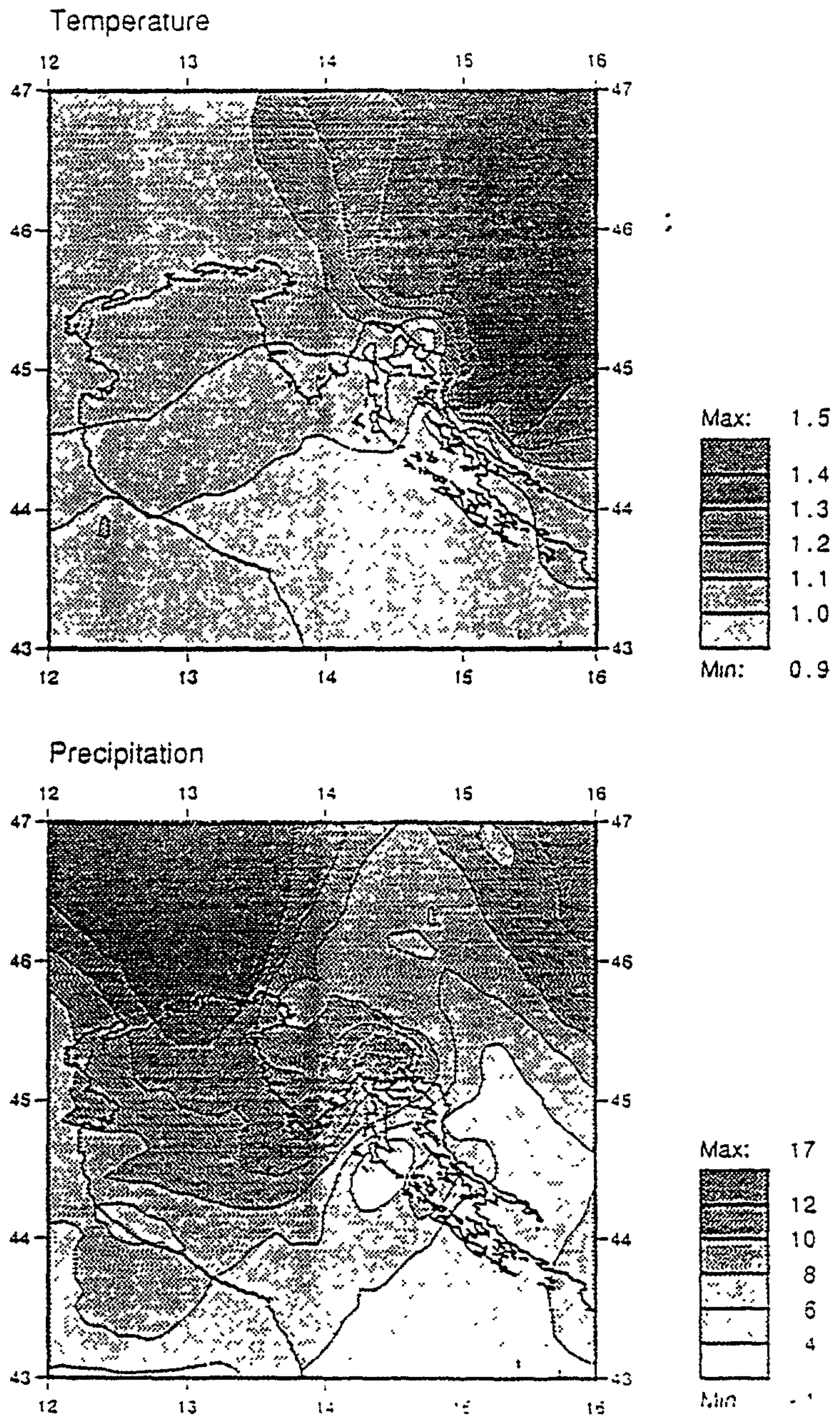

Figure 3 Regional climate scenarios for the northern Adriatic: Spring

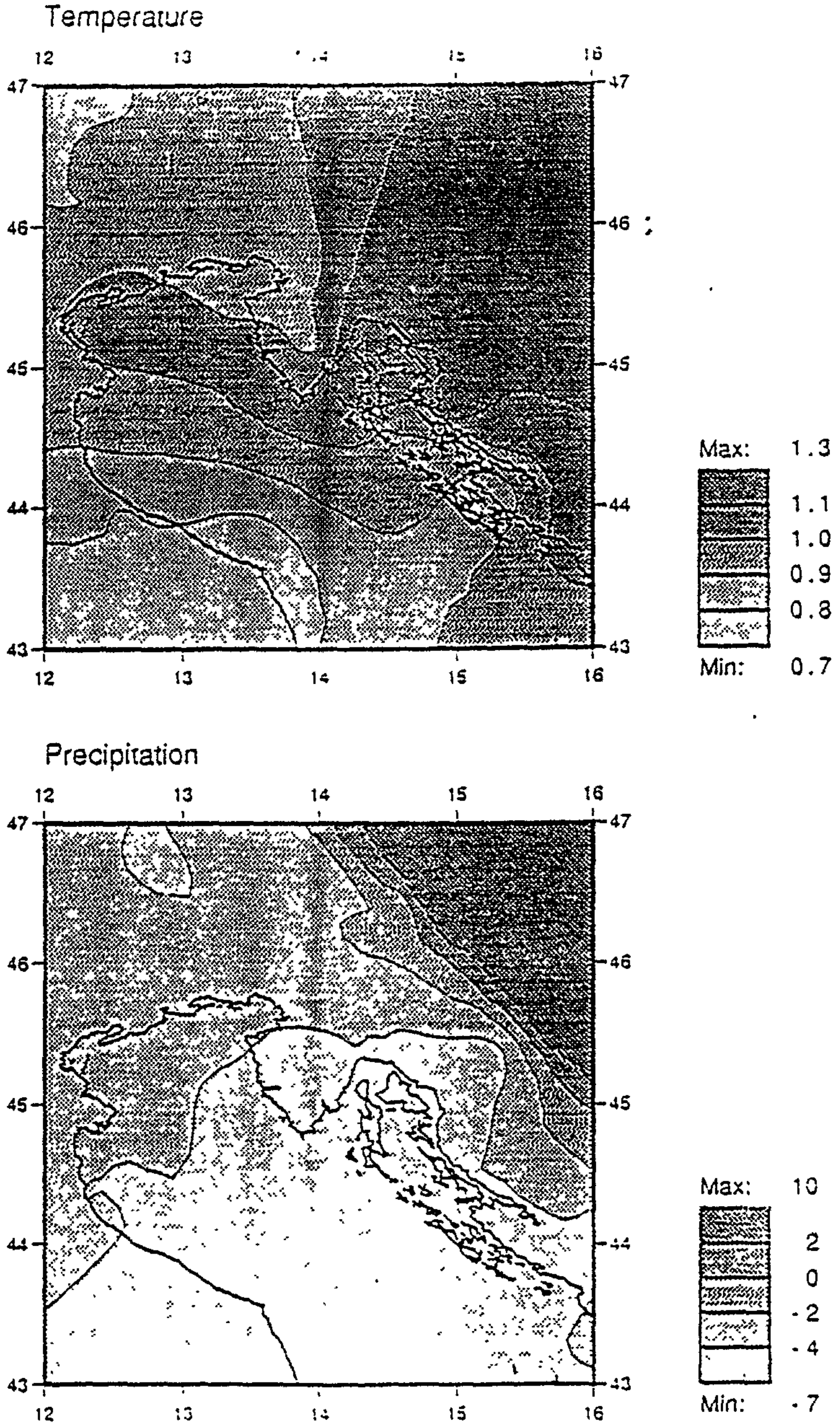

Figure 4 Regional climate scenarios for the northern Adriatic: Summer

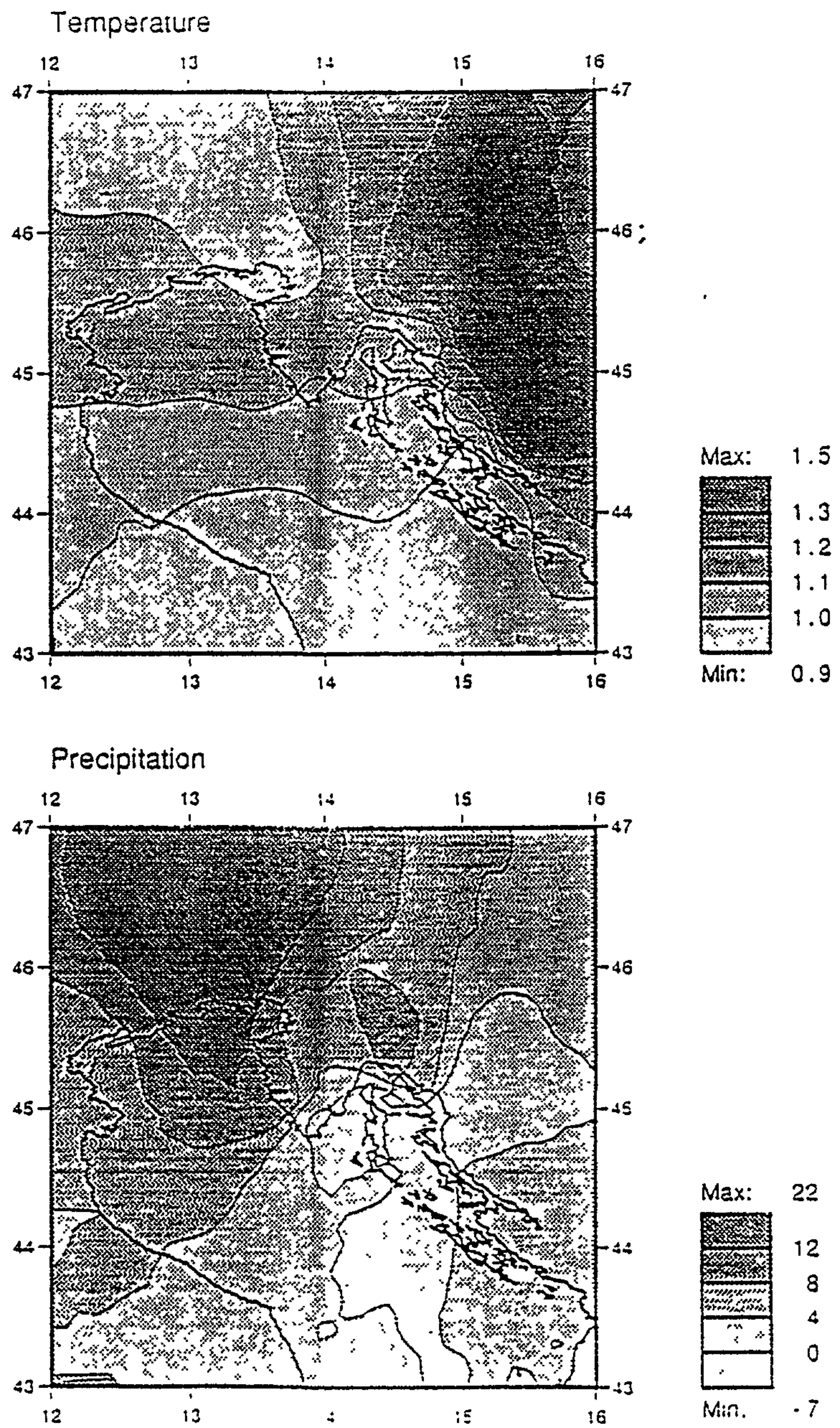

Figure 5 Regional climate scenarios for the northern Adriatic: Autumn

4. CONCLUSIONS

We have applied the methods developed by Kim et al. (1984) and Wigley et al. (1989) to the problem of constructing sub-grid-scale climate change scenarios for the northern Adriatic ares. Regression equations were developed to predict station temperature and precipitation anomalies from regionally-averaged climate anomalies. We proceeded to substitute GCM perturbed-rum minus control-run values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium temperature of each of the four GCMs and average for the four models obtained. The procedure was repeated for every station in the data set, and results contoured to produce a scenario for the northern Adriatic area.

Annual and seasonal scenarios for both temperature and precipitation change were produced. For temperature, the same pattern of change is seen throughout the year, with a sensitivity greater than the global value in the north-east of the study region, and lower than the global value (i.e. less than 1 °C per °C global change) in the south-west and, to a lesser extent, the south.

The scenarios for precipitation are much more difficult to evaluate. At the annual level, there is a trend across the country from an increase in precipitation in the north-west to a decrease in the south-east. The estimated changes are in the range of 13 -5% per °C global warming. This pattern is repeated in three seasons of the year: winter, spring and autumn. The smallest changes are suggested by the spring scenarios (a range of 17 to -1% per °C) and the largest in autumn (a range of 22 to -7% per °C). The summer pattern is rather different, with most of the region apart from the north-east displaying a decrease in rainfall. The problems associated with the construction of regional scenarios of precipitation change associated with the greenhouse effect are discussed at length in the Final Report for the UNEP Mediterranean Project. The confidence that we can place in sub-grid-scale scenarios of precipitation is low.

APPENDIX I

I FOREWORD

The scientific research report about possible implications of the foreseen global climate changes on social and environmental features of Cres and Losinj islands is a part of a larger study within the project "Implications of Climatic Changes on Cres-Losinj Islands" - in organization of United Nations Environment Programme (UNEP/MAP) and the Ministry of Environmental Protection, Physical Planning and Housing of the Republic of Croatia, Sector for the Adriatic - Rijeka.

The report can be divided into two greater parts: first - upon analyzing part of the existing literature on possible implications of world changes of climate, the prognosis is given about eventual consequences of expected changes on social and environmental features of the Cres-Losinj archipelago, and second - upon analyzing the results of empirical research, completed in June 1992 on Cres and Losinj islands, the results are given about the opinion of island population about changes of climate and some already visible manifestations.

It should be stressed that this is the first such research project realized in Croatia, as far as the authors know, therefore the results cannot be studied comparatively, as yet. More firmly based determinants, obtained results and issuing conclusions, and decision making references about this sensitive field could be expected only when, and if, the approach to organize such and similar research projects in regular intervals is made.

The problem of global warming and changes of climate induced largely by anthropogenic makings is not purely technical question, it is in fact the problem with significant political and economical consequences which cannot even be envisioned from present-day point of view. The resulting great sensitivity of the subject is therefore understandable.

The results of this research project should be regarded as preliminary landmarks for larger and more complete sociological and other related research projects - they might hopefully establish mechanisms to mitigate or avoid negative effects of the expected changes of climate.

II IDENTIFICATION AND ASSESSMENT OF POSSIBLE IMPACT OF GLOBAL CLIMATE CHANGES ON SOCIO-ECOLOGICAL CHARACTERISTICS OF CRES-LOSINJ ISLANDS

Anticipation of the global climate changes could be taken as a reliable assumption for the purpose of this report - it is being suggested in some other materials studying the situation on the islands of Cres and Losinj (See: Report of the First Meeting..., 1992). Possible implications on social and environmental features of life of the inhabitants of Cres-Losinj islands could be easily divided into several groups.

First implication. In decades to come (projection, year 2100) the rise of the sea water level (maximum 100 cm) is assumed, even perhaps expected. This could well influence the everyday life of the inhabitants of Cres-Losinj islands in the following aspects:

1. Fishing industry may be disturbed, because port capacities would be unable to harbor and dock safely fishing boats, due to the rise of the sea level, and the new harbors would have to be built (or old ones reconstructed). This is particularly true for the harbor of the town Cres - its harbor is already situated very low with respect to the present sea water level.

2. Three major towns and a number of smaller villages, country houses and other constructions may then be endangered, temporarily or constantly, by flooding due to the rise of the sea water level. It may well be assumed that areas to be hit the most by the rise of the sea water level would be the ones closest to the sea, that

they would be the first to be abandoned, replaced or even transformed into constructions that would be protected against the impact of the sea water. It may be expected that, at first (up to 2050) expected changes of climatic conditions, the mechanical increase of the number of inhabitants in coastal zones of the islands would not be changing essentially owing to the rise of the sea water level. However, if the process of the rise of the sea-water level continues and the process of exhausting non-renewable as well as the degradation of renewable resources is prolonged possible re-distribution of the inhabitants living closer to the sea could be foreseen. In a way, the "life close to the sea" would be, in fact, pushed further back inland - would that represent a kind of an antilittoralization movement?

This would depend not only on local configuration of the coastal zone of the islands (differential influence of the rise of the sea water level), but also on the stimulation of the economical process of moving the centres of development of the islands to other spaces - it should be expected that these moves would be performed in the second period (after 2050) of the expected changes of climatic conditions on the islands.

3. Agriculture is likely to be less endangered by the assumed changes, because the agricultural lands are usually not situated too close to the coast (with exception of Unije field, south-eastern parts of Vele and Male Srakane, part of the island Susak and Kurili areas). In some cases, cultures like olives or vineyards might be hit more by the announced changes, more or less directly, (due to erosion of the soil, salty water pervading the soil, general increase of the salinity of the soil) - but not at so great a scale to be completely abandoned or changed into something else.

4. Sewage systems in close to the sea towns would also be damaged by the assumed rise of the sea water level, but they could be repaired by various technical measures. Analyzing the existing status of the community sewage system has brought to light the fact that, even at present moment, it is the matter of unsatisfactory system of drainage which should be reconstructed in order to avoid the negative effects.

5. In cases of permanent or impermanent flooding of squares in major island towns, it can be assumed that traditional patterns of cultural and social life (as e.g. elder people staying put on the seats of the squares) would be changed a lot. The same could be assumed in case of religious services in the churches which themselves would be hit by the flooding (constant or temporary) in the same way as permanent housing close to the sea.

6. Tourism, the major development activity on the islands, would have to undergo a number of transformations as well. First, the most attractive spots, the ones nearest to the sea, would have to be abandoned. This particularly refers to the recreational objects, situated on the very coast, close to the sea (as camping-sites, marines, intentionally built small yacht harbours, etc.), but also to the beaches, bays and other natural resources of the islands.

Thus, in a way, "the level of attractiveness" of many an interesting spot for tourists would decrease, and in the long run, the whole concept of tourist expansion might have to be changed or radically transformed (particularly if, apart from the possible changes of climate, the potential transformations of social aspiration of tourist in the decades to come are taken into consideration).

If we are to take into account the relatively non-developed economy of the islands, its external dependency (on the continent, on tourism), the general comedown of the level of attractiveness could be a very serious sign of insecure future for the islands. Sea water would, after flooding, stay in many places for longer or shorter periods of time, which could cause the invasions of mosquitoes, or appearance of marshy areas and the similar cases -these also being the possible causes of the decreasing of the level of attractiveness of the whole area. The green areas (woods and parks) situated close to the sea would vanish due to the effect of salty water, which may be considered damaging to the everyday life of the permanent residents and even to temporary guests - tourists. Ships bringing tourists will have to anchor in some other places (perhaps quite distant), as the closest ones will become unapproachable owing to the rise of the sea water level. The existing road communications, they are mostly situated quite close to the sea, could be flooded on a regular basis, and that would require continuous repairing and even building of the new ones. In other words, it would mean that tourists and permanent residents would encounter constant troubles when circulating around islands. However, the assumed impact of the rise of the sea water level would have to be stronger and more visible in ports and port traffic than in island road communications (Baric, A., Gasparovic, F., 1988).

7. The rise of the sea water level and stronger winds would bring about the increase of the danger of not only flooding, but also of ever stronger waves and ever more frequent storms (dynamic movements). In the studied areas, the normal winds which are blowing on a regular basis (NW, for example, SE and NE as well) could even in some cases (stronger temperature contrasts) cause the appearance of bigger waves than expected, which again could lead to the destruction of ports, harbors and houses. It would mean that many life protective measures would have to be taken in future.

8. Finally, local inhabitants are tied psychologically, physically, socially and symbolically to the usual environment. It means that environment, in the long run, would be less controllable, and being constantly devastated would stop being pleasant to be lived in. Indirectly, many towns and settlements which have been, for years, classified as "unchangeable", secure and nice, could be transformed into continually changeable ones, become "repairable" and in existentialist sense, protected and allowing only simple survival. The examples of Venice and settlement at the bottom of Vesuvius seem to be very instructive - the inhabitants are not feeling sure and therefore the decrease of the number of residents there; the wish to put under control one's own life was becoming ever stronger as the environment is less to be controlled.

Second implication. In a few decades, it is assumed that there would be constant rise of temperature, ranging from 1.5 to 4-5 degrees Celsius (while assuming the volume of CO_2 would be doubled). This rise will not be felt in everyday's life, but, in socio-psychological sense, it might bring about reminiscing of greater "pleasantness of" climatic conditions of the past. If we are to skip now possible discussion on the relative importance of these changes, and on the real significance of these changes on a personal level (e.g. health disturbances), we could consider the following major consequences as the result of climatic changes in the future:

1. First, the changes of temperature would bring changes of vegetation features (cycles of growth, quality of the product, types of cultures, cycles of harvests etc.), influencing undoubtedly the ways of cultivating the vineyards, caring for olives and other culture-plantations on the islands; if the vegetation cycle be speeded, it would mean that it might be possible to increase agricultural production. But, at the same time, if the rise of the temperature would increase the number of rainy days, cause more frequent storms etc., the agriculture would be encountering significant negative consequences.

   At the same time, the changes in temperature, as well as the rise of the sea water level could create better conditions for the growth of insects, which could again, directly or indirectly endanger some of the cultures raised on the islands.

In general, as the result of expected changes of temperatures more frequent uncertainties regarding agricultural yields could be assumed and therefore there would appear the necessity for its adapting to the newly arisen climatic conditions but not for the complete and essential changing. Some social processes (migrations, urbanization and the like), already present on the islands these last decades, can be detected as the important generators of changes characterizing more the agriculture of the islands (decrease of the number of farmers - agricultural workers on the islands) than the expected climatic changes would.

2. Tourism, owing to the climatic changes - changes of temperature of Cres and Losinj islands, would, most likely, undergo the changes which might be considered positive and negative.

   Negative effects: the number of the tourists might diminish due to less favourable climatic conditions, the level of "attractiveness" of the environment might, in the long run, bring about the diminishing of the number of tourists, as the tourists motivation to visit the particular destination (islands of Cres and Losinj) would be weakening. The significance of tourism as one of the most important traction forces (business) of this area might possibly decrease, as the attractiveness of the environment might likely diminish by the increase of the rainy days, storms, flooding of the most attractive localities, unpleasant aspect of the surrounding etc.

   Positive consequences: due to certain effects of the expected changes of climate (warmer and drier summer seasons) longer tourist seasons could well be expected, assuming the social aspirations of present day tourist (oriented to bathing and sun-bathing) remained unchanged and there were no problem in supplying drinking water.

3. Local customs and cultural patterns could also be changed due to the changed climatic weather pattern, which would have an implication not only to the indigenous population, but to the level of attractiveness of the place for the outside visitors - tourists. If local "specialties" (food, customs, cultural patterns and the like) are representing the major attractions, then worsening of the climatic weather patterns would equally bring about the diminishing of the attractions of physical and social environment.

Third implication. "Behaving" of the sea and temperature represents two most studied consequences of the expected climatic changes. So, if both mentioned future changes do happen, then the climatic change would be felt as the most significant impression which would influence the whole life of the inhabitants of the islands. It is, though perhaps too early, sensible to assume that these changes would gradually increase to the degree which, in the following century, may result in the following:

1. Depopulation of the islands. If the environment, which is already rather eligible for depopulation due to climatic changes, would deteriorate, then it is sensible to expect the continuation of depopulation process on the islands of Cres and Losinj, though at the present moment the situation may be stagnant due the need of the inhabitants to remain in known natural and social situation.

2. Depopulation would be selective and with far reaching negative consequences - the first to leave the islands would be the members of the youngest generation (with the highest levels of aspirations and high potential for migration). It means that on the islands, and especially the small islands of the archipelago, the demographic structure is going to be even more unfavourable.

3. The possibilities for an expansion of economic activities on the islands - as it has been seen before in this report - are still rather low. It is possible to expect that, on the islands, in case of worsening, the conditions would be even worse and more difficult. It also means that, in the long run, the whole economic activity, particularly tourism, could be very endangered by the expected climatic changes.

The cited changes expected in near future may not appear in such an unfavourable variant but they would establish anew a stagnant situation which again may show a number of unchangeable elements; the situations could be changed only if the local community, together with the global society and with the help from the developed world started a sensible policy which will - on the basis of sectorial prognosis on the change in climate - start a comprehensive policy towards the diminishing of negative effect of the expected changes. It is very likely that - as a result of a kind of policy we are advocating - many new situations and unexpected consequences will arise, but the flexible, future oriented programs of development, which will rely on the operational indicators and research findings and thus ensure easier adaptation to possible permanently changeable situations in future. Such a development orientation might make it possible to avoid individual and partial measures of protection, but the significant difficulties in realization of the program could cause increase of the expenses of the protection against negative effects of climatic changes, thus leading the local and regional communities to avoid completing the protection programs in order to solve presently more pressing problems of the life on the islands.

III MAIN RESULTS OF EMPIRICAL RESEARCH PROJECT ON OPINION OF INHABITANTS OF CRES AND LOSINJ ISLANDS REGARDING POSSIBLE INFLUENCE FORESEEN TO FOLLOW GLOBAL CLIMATIC CHANGES

REMARKS ON METHODOLOGY

1. PROBLEM OF THE RESEARCH

The analysis of the public opinion regarding the possible influence and manifestations of foreseen climatic changes on Cres and Losinj islands is the basic problem of this research project. The analysis is trying to prove the existence (or non-existence) of specific patterns of reactions of the examined people with regards to different dimensions of the research of the problems; it is studying the generators of the differences in the opinions of the examined population.

In accordance with the defined problems of the research project the processed information on the following topics has been gathered:

1. perceiving of the changes of climate at the beginning of the next century;
2. assessing the degree of agreement of different opinions on the changes of climatic conditions;
3. perceiving of possible impact of changed climatic conditions on the further development of Cres and Losinj islands;
4. perceiving the probability of possible climate change and the imminence of the consequences on Cres and Losinj islands;
5. estimation of the means and the need to bring measures for alleviating and avoiding of the negative consequences accompanying climatic changes;
6. assessing the danger from sudden changes of climatic conditions with relation to other natural, technological and social dangers;

7. perceiving certain changes in natural surrounding of Cres and Losinj islands;

8. assessing the degree of received information about foreseen climate changes and their consequences.

2. INSTRUMENTS

For the research work on the terrain the technique of canvassing individuals was used and the assistance of a group of examiners was required.

The research work has been based on the application of the questionnaire CL-1; the questionnaire has been constructed in the following way:

- the questionnaire itself consists of 18 questions (total of 70 variables);

- the questions are constructed so that the answers obtained are of largely closed modalities (with the exception of questions on profession of the examined person and name of the settlement);

- the questionnaire contains two greater wholes: (1) block of questions (instruments) referring to the opinions of the examined persons regarding possible changes of climatic conditions and the resulting consequences on the islands and (2) block of questions (instruments) to establish the basic social, economic and demographic characteristics of the examined persons.

The polling has been made in the period from June 26 to June 30, 1992.

Ten students of the Zagreb University were employed as examiners in the research work on the terrain.

3. RESEARCH SAMPLE

The sample of the examined population the project canvassed consisted of 350 (3% of island population) inhabitants of Cres and Losinj islands. The construction of the mixed sample (combination of zone and random quota samples) for this research has been made on the basis of criteria specific to the problems the research has been dealing with.

The first criteria was **the size of the settlement** the examined person lived in. On the basis of existing demographic information on the settlements system of Cres and Losinj archipelago the sample has had to include 25% of examined persons from the community centre (Mali Losinj), from community sub-centre (Cres), from the local centres (Veli Losinj, Nerezine, Cunski, Jakov, Martinscica, Osor, Orlec, Belej, Punta Kriza, Valun, Loznati), as well as from smaller settlement and islands (Lubenice, Pernat, Mali Podol, Stivan, Ustrine, Vodice, Zbicina, Luzani and Unije).

The other criterion has been **the type of settlement** in which the examined person was living. The sample has encompassed the inhabitants of the settlements of different categories (town, more urbanized, less urbanized and rural), all within the previously defined proportions defining the size of the settlement.

The third criterion has been the definition of the settlement **zone of potential danger** of negative consequences of the foreseen climate changes. The sample has encompassed the inhabitants of narrow coastal area (supposed to eventually suffer the greatest impact of the rise of the sea water level) as well as the inhabitants of the inland area of the islands (supposed to be receiving rather strong impact of indirect consequences of climatic changes).

4. DATA PROCESSING

The data have been processed basically upon univariant statistical techniques to calculate the frequencies and percentages of studied variables (70) for all the examined individuals (350).

In order to determine various tendencies among the examined persons bearing the features that may potentially be separating out social groups which would then show differentiated attitudes towards the examined problems, the bi-variant, non parametric techniques of hi-squared test (hi^2)[1] have been used to calculate statistically significant differences among variables as well as the analysis of the coefficient of contingency C_k) to determine the degree of relations among variables. It has been studied how the sex, age, level of education, the size of settlement in which the examined persons live as well as the length of stay on the island, influence the shaping of the polarized opinions of the examined persons regarding different aspects of the studied problems. How the greater amount of information offered to the examined population and improving of their understanding of the inevitability of the approach of climatic changes would influence the opinions on the probability of climatic changes and the consequences have been analyzed. The analyses have determined several statistically significant differences on the level of less than 5% of risk.

RESULTS OF THE RESEARCH

1. BASIC FEATURES OF THE EXAMINED POPULATION

The age structure of the examined population (**question 11**) has been the following: 33 (9.4%) of the examined up to the age of 25, 71 (20.3%) of the examined of the age between 26 and 35, 75 (21.4%) of the examined of the age between 36 and 45, 43 (12.3%) of the examined of the age between 46 to 55, 47 (13.4%) of the age between 56 to 65, and 81 (23.1%) of the examined of the age of 66 onwards.

Among the examined persons there were 174 (49.7%) men and 176 (50.3%) women (**question 10**).

The data on the level of education (**question 12**) point to the following structure of the examined persons: 23 (6.6%) of the examined have no schooling, 109 (31.1%) of the examined completed 8 years of schooling, 165 (47.1%) have completed secondary schooling, 52 (14.9%) attended higher and high schools, and one examined person (0.3%) has obtained Master's degree as well as Doctorate of Sciences.

The structure of the profession of the examined sample group (**question 13**) has shown the following structure: farmers-workers in agriculture - 16 (4.6%), workers in material production - 25 (7.1%), workers not in material production 50 (14.3%), employees in offices 29 (8.3%), experts and artists 33 (9.4%), private craftsmen 29 (8.3%), civil service and guard employees (MIA, CA, firemen brigades), 4 (1.1%), pupils and students 4 (1.1%), housewives 66 (18.8%), pensioners 57 (16.3%), fishermen 7 (2.0%), sailors 14 (4.0%) and unemployed 16 (4.6%).

The data on the length of the examined persons stay on the island (**question 17**) point to the following distribution on the sample: majority of the examined, 189 (54.0%), have been born on the island, 5 (1.4%) of the examined persons have been living on the island for more than 50 years, 36 (10.3%) of the examined person have been living on the island for 30 to 50 years, 82 (23.2%) of the examined have been living on the island for 10 to 30 years, and 39 (11.1%) have been living less than 10 years.

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[1] We would like to stress that hi^2 -test does not give cause-effect connection of the variables, it only points to the probability of their being connected.

The obtained data on the number of settlements canvassed according to the size (**question 18**) have shown the following distribution: in town centres of the islands of Losinj and Cres 175 of persons have been examined, which makes 50% of the total number of the examined persons, in the local centre 121 person have been examined which makes 34.6% of the total number and 54 have been examined in smaller rural settlements, which makes 15.4% of the examined.

350 persons have been canvassed in the polling and it makes 3% of the total islands' population.

2. ANALYZING RESULTS[2]

2.1 Perceiving of the changes of climate at the beginning of the next century

Question 1. The answer would hopefully give an insight into the opinion of the examined persons regarding the climate perspectives at the end of this and the beginning of the next century. The given opinions on the possibility of climate changing show that 42 (12.0%) of the examined persons think that there will be no change of temperature, while 103 (29.4%) of the examined persons do not know and cannot make an assessments on possible range of impact of changed climatic conditions. However, the majority of the examined persons (58.6%) believe that next century will bring the change of climatic conditions, but the examined persons have the difference of opinion regarding the assessment of the intensity of the expected climate changes. Thus, 140 (40.0%) of them believe the changes of climate will be gradual and mild and will, therefore, not significantly upset the life of people, while 65 (18.6%) of these examined persons consider the changes of climate will be more radical, causing the damage and great disturbance in the life of people. Quite indicative seems to be the fact that none of the examined persons expressed belief of the expected climate changes bringing more favourable conditions for the life of man on the Earth.

Perceiving of the changes of climate at the beginning of the next century	
1. There will be no change of climate	12.0
2. The change of climate will be gradual and mild, therefore there will be no significant disturbances in life of people	40.0
3. The change of climate will be sudden and unexpected, therefore there will be great damages and great disturbances in the life of people	18.6
4. New, more favourable conditions of life of people on Earth will be brought by the changes of climate	.0
5. I do not know, I cannot make an assessment	29.4

The analysis has confirmed two statistically significant differences in opinions of the examined population regarding the imminence of the approach and possible intensity of the climate changes. The opinions of the examined persons who are expressing the fact that they have not been given enough information on different forecasts regarding changes of climate rather vary from the opinions of the examined persons (hi^2 =39.41, Ck=.32) who consider themselves partly or well informed on the matter.

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[2] Data expressed in the tables are summarized and are expressed in percentage. Some questions are additionally discussed and the arithmetic mean given (x). Complete presentation of data is given in corresponding table in appendix.

A tendency has been confirmed: the examined persons who do not consider they have been given enough information largely expressed the opinion that there will be no change of climate or say that they cannot make an assessment regarding the complexity of climate problems in the next century; on the other hand, better informed examined persons seem to be believing more in approaching of certain aspects of climate changing.

The other important difference ($h^2 = 16.62$, $C_k = .21$) has been discovered between the opinions of the examined persons from rural settlements on the islands and those from the town settlements of the island. The examined persons from smaller rural settlements and local island centres show more openly the impossibility of making an assessment regarding the complexity of the climate problem, and they also form more widely the opinion that there will be no change of climate. At the same time, population of urbanized settlement more readily believes in the close approach of worldwide changes of climatic conditions.

The stated differences bring no surprise. The obtained results suggest that the level of information influences widely the difference in perceiving the climate changes as a world-wide phenomenon. In fact, it could be assumed that the examined persons of the smaller island settlements cannot (being mainly elder inhabitants, of lower standard of life, of quite traditional system of values, of lesser interest field and lesser space and communication mobility) be better informed about climate changes, while the examined persons from bigger (town) settlements seem to be more accessible to different forms and media of communication - information obtaining.

2.2 Assessing the degree of agreement of different opinions on the changes of climatic conditions

Question 2. The purpose has been to obtain as the result the degree of agreement of the examined persons regarding several different opinions on possible changes of climate . To decide on the opinions of the examined persons on the given statements, the numeric scales of Likert type have been used as the instrument - the examined persons had to express the degree of agreement, i.e. of accepting or rejecting of the given statements within the interval ranging from 1 to 5 (1 = I completely disagree, 2 = I disagree, 3 = I do not know, I am not sure, 4 = I agree, 5 = I agree completely).

Analyzing obtained answers to the offered statements in the questionnaire, the hierarchy of acceptance of particular opinions about climate changes was established. The preferred opinions about the degree of agreeing with particular statements show that among the examined inhabitants largely spread opinion is that disastrous consequences could be avoided only by giving up the present-day type of industrial development (x=3.64). The impossibility to reach any more defined assessment has been explained, by the examined persons, with the fact that the science and new technological solutions might prevent the possible damaging effects of the climate changes (x=3.27), that the balance in nature is so powerful it would prevent possible damaging effects arising from the change of climate to happen (x=2.81), and finally, that no human effort or man-made device could stop changes of nature (x=2.81). Least accepted opinions among the examined population are those claiming that man cannot ever influence the changes of climate, therefore the problem should not be considered as over important (x=2.46), and that it is already too late to stop the damaging effects of the changes of climate which would be soon manifested (x=2.30).

Assessing the degree of agreement of different opinions on the changes of climatic conditions

	1.2	3	4.5	x
1. It is too late to prevent the damaging effects the climate changes might bring	61.7	30.6	7.4	2.30
2. Balance of the nature is so strong it will repress the damaging consequences the climate changes may occasion	37.1	38.3	24.3	2.81
3. Disastrous consequences of the climate changes may be avoided by giving up the present way of industrial development	7.4	31.4	61.2	3.64
4. Man cannot control the changes of climate, therefore he should not give too much attention to the matter	58.3	20.9	20.9	2.46
5. No human effort or device could stop climate changes from happening	40.3	30.0	28.8	2.81
6. Science and new technologic solutions will prevent possible damaging effects caused by climate changes	15.4	43.7	40.9	3.27

Obtained results show that there exists a positive aspirations potential among the examined persons aiming at preventing or avoiding the damages that might arise from the changes of climate, while the giving up of the present-day industrial development programs seems to be the basis for forming personal assessments on possibilities of preventing climate changes. Though, quite indicatively, the science and new technological solutions, accepted enough, are not felt to be the main factors in preventing possible damaging effects - the given answers can be located in the zone of medium acceptance, i.e. in the answers: "I do not know, I am not sure."

2.3 *Perceiving of possible impact of changed climatic conditions on further development of Cres and Losinj islands*

Question 3. *It should have offered the inference on the opinions of the examined persons regarding* the possibilities of potential climate change on determining further development of Cres and Losinj islands. Half of the inhabitants (50.3%) considers that the eventual climate changes might strongly influence and even completely determine the further development of the islands, 71 (20.3%) of the examined persons cannot make an assessment regarding the impact, while 102 (29.2%) of the examined persons thinks the climate changes would not have much influence on or would not at all influence the further development of the islands.

Perceiving of possible impact of changed climatic conditions on the further development of Cres and Losinj islands

1. It would have no impact or it would not have greater impact on further development of the islands	29.2
2. I do not know, I cannot make an assessment	20.3
3. It would have great influence or it would completely determine further development of the islands	50.3

The analysis has also confirmed that there are several statistically significant differences in the examined persons attitude regarding the assessment of possible impact of change of climate on the development of the islands. According to the given answers, the main generators of the differences of the opinions of the examined persons seem to be: how well the person was informed, the age and education level.

It has been found that the examined persons, who consider they have not been well informed about different forecasts on changes of climate, have more tendency to claim that the eventual climate changes will not influence further development of the islands, and that they cannot make an assessment as to the impact the expected changes would make, while better informed examined persons consider that the changes of climate would greatly, even crucially influence the development of the islands (hi^2 =56.35, C_k =.37).

Furthermore it has been established that the examined person under 25 and those older than 50, show more tendency to believe the eventual climate changes will not have quite so much influence on the further development of the islands, while the medium age population (25 to 45) believes more that the climate change will determine further development of the islands (hi^2 =42.51, C_k =.33).

It has been noticed that the examined persons of higher level of education vary from not so well educated population by accepting more the possibility that changes of climatic conditions would , more essentially, determine the further development of the islands (hi^2 =128.40, Ck=.52).

If the determined differences of the opinions of the examined population are taken into account, it seems more clear that, with due precaution, in this social space two groups of the examined persons can be separated with regards to the opinion on possible impact of climate changes: the first - the group of elderly, not highly educated and relatively poorly informed examined persons (in certain dimensions of the tested problems the examined persons under 25 years of age can be added here), and the second - group of the examined persons of middle age, better educated and partly informed on possible changes of climatic conditions.

2.4 Perceiving the probability of possible climate change and the imminence of the consequences on Cres and Losinj islands

The examined persons have been asked to estimate the probability of some of the climate changes and the consequences happening in near future on Cres and Losinj islands (**question 4**). To process the data on opinions of the examined on this problem, numeric scales of Likert type have been used - the examined person should have expressed their own opinion regarding the probability of each climate change and their consequences happening in the interval ranging from 1 to 5 (1 = it will certainly not happen, 2 = it will probably not happen, 3 = I do not know, I cannot make an assessment, 4 = it will probably happen, 5 = it will certainly happen).

Analyzing the obtained answers, the following distribution has been determined. The examined persons consider that the changes to happen on the islands in near future are: features of seasons will change (x=3.87), health problems will increase (x=3.60), the island flora and fauna will change (x=3.40), the length and frequency of dry season will increase (x=3.40). They could not assess the probability of happening for the majority of the manifestations of climate changes and their consequences. According to the examined persons, the least probable phenomena seem to be the increased emigrating of islanders from the islands to the continent (x=2.48), as well as the inhabitants of the narrow coastal area emigrating to inland of the islands (x=2.42).

Perceiving the probability of possible climate change and the imminence of the consequences on Cres and Losinj islands

	1.2	3	4.5	x
1. Mean air temperature will increase	20.3	33.4	45.7	3.28
2. Level of the sea water will rise	19.4	39.1	41.2	3.23
3. Temperature of the sea water will rise	19.7	37.4	42.6	3.24
4. High tide waves will come on	28.8	50.3	20.6	2.87
5. Frequency of storms will increase	24.3	46.0	29.4	3.04
6. Frequency and length of dry seasons will increase	14.8	33.4	51.7	3.40
7. Frequency and length of rainy seasons will increase	22.0	38.3	51.7	3.19
8. Features of seasons will change	6.9	16.9	75.7	3.87
9. There will be greater emigration movements of the inhabitants of the narrow coastal area towards inland	56.8	28.6	14.5	2.42
10. There will be greater emigration movements of the islanders towards the continent	54.9	28.9	16.0	2.48
11. Health problems will increase	13.8	27.4	58.6	3.60
12. Flora and fauna of the island will undergo changes	19.8	27.1	53.1	3.40

Such results show that the examined persons consider that the consequences of the expected climate changes will reflect more on natural eco-systems (soil, water, sea, vegetation and the like). The consequences of eventual climate changes on local community are seen by the islanders as: the impact of the expected climate changes will fall stronger on the health of the inhabitants than on the space mobility. In other words, the examined persons believe that the negative consequences of the expected climate changes will not be so great as to cause migration movements of the inhabitants, but will still strongly influence the change of the personal level and quality of life, i.e. of the health of the inhabitants of the archipelago.

Bi-variant statistical analysis of the results determined the following differential implications on the examined persons in social field:

* the examined persons, who claim they are well informed on different forecasts regarding the climate changes and their consequences, largely believe that, in near future,the average air temperature will rise on Cres and Losinj islands (hi^2 =19.96, C_k =.23), then that the sea water level will rise (hi^2 =18.87, C_k =.23), that the frequency of storms will increase (hi^2 =25.56, C_k =.26) as well as the frequency and length of dry seasons (hi^2 =29.08, C_k =.28), and that the features of the seasons will change (hi^2 =21.63, C_k =.24) as well as the archipelago flora and fauna (hi^2 =37.77, C_k =.31);

* the examined person who have higher level of education are mostly believing in the possibility of the rise of mean air temperature on the islands (hi^2 =68.51, C_k =.41);

* female part of the examined population mainly shows indecision in assessing the probability of particular climate changes and their consequences happening (particularly regarding the sea water level rise, rise of mean temperature on islands, on-coming of big tidal waves, and increase of frequency of storms);

* the examined persons from bigger island settlements believe more that the expected climate changes and pertaining consequences will manifest as the following: rise of the sea water level (hi^2 =22.48, C_k =.25), higher temperature of the sea water (hi^2 =26.53, C_k =.27), greater emigration movement of the inhabitants from the narrow coastal area to the inland of the island (hi^2 =19.09m C_k =.23) and the greater emigrating of the islanders to the continent (hi^2 =21.87, C_k =.24);

* the examined persons from the smaller rural settlements mainly show indecision in assessing the probability of particular climate changes and their consequences happening, though they believe more in possible changing of the features of the seasons (hi^2 =24.45, C_k =.26) and greater frequency and length of dry seasons on the islands (hi^2 =15.78, C_k =.21).

2.5 Estimation of the means and the need to bring measures for alleviating and avoiding the negative consequences accompanying climate changes

Question 5. It was to help determine the opinion of the examined person on ways of preventing and alleviating the possible negative consequences of climate changes, and to determine on time of their application. To analyze the islanders opinions on this dimension of the problems, numeric scales ranging from 1 to 5 have been used (1 = not necessary at all, 2 = necessary at the appearance of the first consequences, 3 = necessary immediately, 4 = too late for the measures, 5 = I do not know, I cannot make an assessment).

Analyzing the obtained results we found that the examined persons consider that almost all the measures should be started on immediately to alleviate, efficiently and on time, the negative effects of the expected changes of climate. The only measure seemingly not so accepted by the examined persons has been the building of protection walls and embankments as means to alleviate consequences of the rise of sea water level.

Estimation of the means and the need to bring measures for alleviating and avoiding of the negative consequences accompanying climatic changes

	1	2	3	4	5	x
1. Building protection walls and embankments in order to alleviate the consequences of the rise of sea water level	41.7	24.3	8.0	1.1	24.9	2.43
2. Withdrawing the working permission to the industrial plants whose work adds to the causes of changes of climate	8.6	14.0	61.1	3.4	12.9	2.98
3. Bringing stricter laws regarding environmental pollution	2.6	7.7	78.3	1.4	10.0	3.08
4. Changing from the use of fossil fuels (coal, oil, gas) to the use of new renewable fuel resources (wind, sun, waves)	3.4	8.9	69.1	1.4	17.1	3.20
5. Obligation to build in catalyzing filter devices for industrial waste gases	4.6	6.3	76.0	1.7	11.1	3.08
6. Bringing stricter laws to prohibit new construction building in narrow coastal area	5.7	8.3	66.0	1.4	18.6	3.18
7. Adapting economy development plans to new knowledge on eventual consequences of changes of climate	1.4	10.0	64.6	.6	22.6	3.31
8. Intensifying reforesting of the islands	21.4	12.3	56.9	.6	8.6	2.62

The shown results are suggesting relatively high consciousness of the examined persons who, assessing the particular measures, rather openly show they support the idea to have the efficient protection from negative climate changes realized and that should be done by respecting all mentioned measures which should be applied immediately. Rejection of building the protection coastal walls seems relatively easy to explain not only by the examined persons trusting the possibility of the efficiency of other preventive measures that are to be undertaken, but also by their perceptive and symbolically related feelings towards the present- day appearance of the area. It seems reasonable to assume that potential construction of the protection coastal walls is felt as a measure which would have strong impact of the present-day appearance of the coast-sea contact area, therefore its application is to be expected in event of the danger of greater rise of the sea-water level (adaptive measure).

Bi-variant statistical analysis of the results defined the following differential matter influencing the examined persons on the social field:

* elder examined persons (especially those over 66) show greater indecision in assessing value of the particular measures for protection and the need to bring measures for alleviating and avoiding negative consequences of climate changes;

* female part of the examined population shows greater indecision in assessing the need to close down the industrial plants the work of which adds to the cause of climate changes (hi^2 =11.10, C_k =.18), while,in case of the need to construct protection coastal walls and embankments for alleviating the consequences resulting from the rise of the sea-water level, they are more supporting the application of the measures with the appearance of the first consequences of the rise of the sea-water level (hi^2 =13.57,C_k =.19);

* the examined persons with not so high level education (particularly with elementary schooling) are also showing more indecision in assessing the need for the use of protection means and for bringing the measures to alleviate and avoid negative consequences of climate changes and are having more rejecting attitude towards the need of bringing particular measures to alleviate and avoid negative consequences of climate changes;

* the examined persons, who say they have not been properly informed on different forecasts regarding climate changes, are showing more indecision when it comes to assessing the need for particular measure, or are even opposing the need to bring particular measures to alleviate and avoid negative consequences of changes of climate.

* the examined persons from smaller rural settlements show more indecision in assessing the need to bring particular measures to alleviate and avoid the negative consequences of changes of climate.

2.6 Assessing the danger from sudden changes of climatic conditions with relation to other natural, technological and social dangers

Question 6. The examined person have been asked to evaluate in what measure some natural, technological and social problems are already upsetting the life of Cres and Losinj islands. To determine the opinion of the examined persons regarding this problem, numerical scales of the interval ranging from 1 to 4 have been used (1 = it does not upset at all, 2 = it is partly upsetting, 3 = it is very upsetting, 4 = I do not know. I cannot make an assessment).

Analyzing the ranges of the obtained answers it has been discovered that the examined persons are perceiving the enumerated problems as partly upsetting, with the exception of the danger from the damages to the ozone layer (x=2.65) and of bad tourist seasons (x=2.60) - those are felt to be greatly upsetting problems.

Assessing the danger from sudden changes of climatic conditions with relation to other natural, technological and social dangers (x)	
1. Industrial waste pollution of the sea waters	1.90
2. Crashes of the ships transporting dangerous loads (chemicals, oil etc.)	2.11
3. Damage of the ozone layer	2.65
4. Accidents in nuclear power plants	2.32
5. Air pollution from industrial sources	1.81
6. Air pollution from traffic fumes	1.60
7. Pollution of foodstuffs (by pesticides and the like)	1.86
8. Pollution of drinking water	1.75
9. Sudden changes of the climate	2.10
10. Disappearance of several sea and land fauna species	2.29
11. Natural catastrophes (earthquakes,long dry seasons, hurricanes and the like)	2.08
12. Non-organized waste dumps	2.33
13. Forest fires on the islands	2.32
14. Lack of drinking water	1.74
15. Decrease of number of islands inhabitants	2.07
16. Bad tourist seasons	2.60
17. Increased settling of the inhabitants not born on the islands	1.88
18. Neglecting the development of the inland settlements	2.30
19. Disappearance of the particular way of life on the islands	2.39

The shown results point to the conclusion that, the risk of climate changes in context of other natural, technological and social changes represents only partly upsetting problem, while the weakening of tourism, that strongest economical and attraction power of the islands, as well as the enlarging of the ozone hole, the better known world-wide phenomenon (as it had been more exposed in the media and the consequences being of a more sudden nature), seem to be more serious problems at present.

2.7 Perceiving certain changes in natural surrounding of Cres and Losinj islands

Question 7. It was to help establish whether some of the possible manifestations of climate changes have been perceived on the personal level as well, i.e. whether the examined persons have been noticing some more permanent changes in nature on Cres- Losinj archipelago these last decades.

Analyzing the ranges of the obtained answers it has been determined that the inhabitants of Cres and Losinj islands are perceiving the following changes in nature: the catch in fishing has been diminishing (x=.78), some rare phenomena of nature have become more frequent (x=.79), the features of the seasons have been changing (x=.78), the frequency and quantity of precipitations have changes (x=.7), the field cultures yields have diminished (x=.63), the number of certain animal and plant life form has been decreasing and some animal and plant species have even disappeared (x=.61).

Perceiving certain changes in natural surrounding of Cres-Losinj islands	No	Yes	x
1. Are some fauna and flora species decreasing in number or disappearing?	38.3	61.4	.61
2. Are there changes in frequency and quantity of precipitations?	23.7	76.0	.76
3. Are there changes in frequency and length of dry seasons?	24.6	75.1	.75
4. Are there changes in directions and strength of winds?	65.7	34.0	.34
5. Are there changes in features of seasons?	21.1	78.6	.78
6. Are there changes in level of tides?	70.3	29.1	.29
7. Are some up-to-now rare natural phenomenons becoming any more frequent ("blossoming of the sea", "invasion of jelly-fish" etc.)	20.9	78.9	.79
8. The bottom of the sea and the features of the bottom are changing	60.3	38.9	.39
9. The coast area is crumbling off and sandy bays are becoming smaller	80.9	18.3	.18
10. Some smaller islands and rocks have been overflown	94.9	4.0	.04
11. Fishing catch is diminishing	17.7	82.0	.82
12. Agricultural cultures yields are diminishing	36.0	63.4	.63

2.8 Assessing the degree of received information about foreseen climate changes and their consequences

Questions 8 and 9. They were to establish in what portion the examined persons have been informed on different forecasts regarding climate changes and whether there are aspirations for obtaining better additional information.

Almost half of the examined persons (46.6%) claim they were poorly informed on different forecasts regarding expected climate changes, 48.0% of the examined person have been partly informed, and only 5.4% of them have been well informed.

Assessing the degree of received information about foreseen climate changes and their consequences	
1. I have not been informed	46.6
2. I have been partly informed	48.0
3. I have been well informed	5.4

70.6% of the examined population aspire to be receiving additional information on the matter.

IV CONCLUSIVE REMARKS AND RECOMMENDATIONS FOR FURTHER ACTIVITIES

Conclusive remarks about possibility of impact of foreseen world-wide climate changes on Cres and Losinj islands rely on characteristic results which have been obtained through a scientific and critical evaluation of the existing documents, but also largely on the data provided and collected by the questionnaire polling which is the result of the sociological research - the data have been presented in this report.

GENERAL CONCLUSIVE REMARKS

1. The foreseen world-wide changes of climatic conditions expected to be happening during next century will have an impact on natural and man-made environment of Cres-Losinj archipelago, but it will not be uniform nor evenly spread.

It is expected that the natural eco-systems of Cres-Losinj archipelago (soil, water, sea, vegetation and the like) will suffer greater impact.

2. Influence of the local climatic conditions of the islands upon man-made environment cannot be studied separately from the changes occurring on regional and global plan which could have influence of slowing down or speeding up the local climate changes.

Implications of foreseen changing of global climatic conditions on the man-made environment cannot be considered separately from other social processes and activities on the islands as they, too, can influence the speeding up or slowing down of appearance of manifestations of foreseen climate changes on local plan.

3. The foreseen changes of global climatic conditions, expected during next century, will have a limited impact on the inhabitants of Cres-Losinj archipelago - it will be the result of possible " adapting time " of the society to the changes of climate.

It is expected that the foreseen changes of the global climatic conditions will not significantly influence the distribution and growth dynamics of the inhabitants of Cres and Losinj islands until 2050.

A more significant influence of the foreseen changes of global climatic conditions on distribution of islands inhabitants will be in the second phase-period of the expected changes (after 2050).

It has been estimated that the rise of the sea-water level will result in more negative consequences on man-made environment of Cres-Losinj archipelago.

4. Criteria for choosing from the social strategies of development of the islands, for choosing particular sources of power or for applying of a new technology should be supplemented with new knowledge on implications of expected climate changes.

In a narrower sense, the problem of impact of foreseen global climate changes on man-made environment can be reduced to the procedure of determining the zones of possible impact and criteria to measure the degree of risk prompted by the changes of climatic conditions, and the estimation about the necessity of measures to alleviate and avoid the negative consequences of climate changes.

The approaching world-wide changes of climate are expected to hit, on a greater scale, the inhabitants of lower coastal areas (parts of Cres, Mali and Veli Losinj, Osor, Nerezine, Susak and Ilovik islands, and 5 smaller settlements on the islands) - it means about 13% of population of community (estimate of Urbanisticki institut Republike Hrvatske - Institut for Urbanism of the Republic of Croatia).

5. The alleviating and avoiding of negative influencing of expected global climate changes on the man-made environments on Cres and Losinj islands, will have grave financial effects as well as organizational consequences for the further development of the islands community.

SPECIFIC CONCLUSIVE REMARKS

On the basis of collected data the sociological research could single out the following conclusive statements:

* More than half of the examined population (58.6%) believe that next century will bring the change of global climatic conditions. At the same time, greater part of the examined (40%) believe that the change of climate will be mild and, therefore, will not cause any serious disturbance in the life of people - so much so that it is possible to state that a part of the examined person feels that adapting to possible climate changes will the most acceptable pattern of personal behaviour.

* There is a belief recognizeable in all the examined group - you can influence on the consequences of climate changes, there is, as well, a positive aspiration potential - aspiring that negative consequences resulting from expected climate changes be stopped or alleviated, so much so that it has been possible to state that, when it comes to the causes of climate changes, the examined persons consider the science and technology partly responsible for on-coming changes.

* More than half of the examined populations (50.3%) consider that the expected changes of climatic conditions could greatly influence, even completely determine, the further development of the Cres-Losinj archipelago.

* The examined person consider that the impact of the expected climate changes will be reflected, on a greater scale, on the natural eco-systems of the islands. According to the examined persons, negative consequences of the expected climate changes will not be so extended to cause migration movements of the examined persons, they will have stronger influence on quality level of personal life, i.e. influence the changes in health status of the islanders.

* Evaluating particular means as well as the need to bring a number of measures to alleviate and avoid the negative consequences of the climate changes on islands, the examined persons show the wish to immediately apply almost all the measures, with the exception of construction of protective coastal walls and embankments which are supposed to alleviate the impact of the rise of sea-water level on the environment - thus it is possible to state that it is the matter of latent social-conflict measure and that its application will be possible only after sensitizing the local inhabitants has been performed, and that the application will be possible only as a short-term solution and only after the first signs of the negative consequences for islands became visible.

* The examined person do not make good differentiation of various potential natural, technological and social dangers. The weakening of the tourist activities and enlarging of the ozone hole are felt to be serious problems.

* On the basis of this research it has been possible to valorize and evaluate the implications of particular socio-demographic variables on the differences of opinions:

1. **Level of education and obtained information** about the examined problems appear to be key variables in taking attitudes and behaving with regards to the examined problem. The results are showing that the examined persons with higher level of education and better informed ones are more definite in their assessing the examined problem, and are more precise in their assessment of particular climate changes and the possible implications they might have for the society, than the ones who are not so well informed and are not too highly educated.

2. **Sex difference** has brought certain polarization of the attitudes among the examined islands population. Female part of examined population shows greater indecision and more neutral attitudes regarding the expected climate changes and the possible consequences.

3. **Age of the examined persons** also appears to influence the forming of difference of opinions regarding the examined problems. As a rule, younger examined persons as well as the oldest ones seems to show greater indecision and more neutral attitude regarding the expected climate changes and the implications they might have.

4. **The type of settlements** in which the examined persons live appears to have become a discriminate variable giving firm basis for differentiated attitude of the examined persons. The examined persons from smaller island settlements show more indecision in assessing the implications the possible climate changes may have, while the examined persons from island urban centres are more specific in their assessing of particular dimensions of the examined problems.

RECOMMENDING ACTIVITIES

Synthesis of the results obtained by sociological research ensures forming of the following recommendations and suggestions:

* On the basis of new scientific knowledge about implications of expected climate changes it *seems necessary to supplement criteria for choosing between particular social and economic strategies* for the development of the islands, and for choosing particular power sources and applications of new technologies.

* Developing prevention and adaptation strategies to alleviate and avoid negative effects of expected global climate changes.

* Developing regionally based strategies for reducing risks from the expected world-wide climate changes and global warming.

* Introduction and enforcing of the application of a number of measures within the development programs of the islands, as:

- centering attention to the development of "ancillary forms. of tourism" (e.g. organization of tourist visits to the farms and small villages in the central part of the islands, organization of hunting or photo-safaris, stimulating traditional ways of life on the islands, organization of "country style" tourist offer, accommodation in natural surrounding etc.);

- organizing policy of employing which could draw younger inhabitants to stay on the islands (tax reductions, favourable crediting in agriculture, fishing, cattle raising and the like);

- construction of new transport communication system which would connect the interior of the islands with the coastal area etc.

* Establishing a system of constant supervision (monitoring) of the status of the environment to enable timely prevention of possible negative consequences of expected climate changes whether on local or regional level.

* Organizing management of the environment in cooperation with local inhabitants, local experts, as well as experts from other countries (experts on international programs of environment protection) who will be continually informing the local, state and international communities about changes in natural and social environment caused by changing of global climatic conditions.

* Starting a longitudinal sociological and related research programs about adaptation of social and technological systems to changes resulting from changes in global climatic conditions.

TABLE 1

1. There are certain different assessments regarding the climate changes at the beginning of the next century. Give us your own opinion on possible climate changes (Mark only one answer).	
1. There will be no change of climate	12.0
2. The change of climate will be gradual and mild, therefore there will be no significant disturbances in life of people	40.0
3. The change of climate will be sudden and unexpected, therefore there will be great damages and great disturbances in the life of people	18.6
4. New, more favourable conditions of life of people on Earth will be brought by the changes of climate	.0
5. I do not know, I cannot make an assessment	29.4

TABLE 2

2. Several different opinions on changes of climate are cited below. Mark the degree of your agreement with each one of the statements.						
1. It is too late to prevent the damaging effects the climate changes might bring	.3	15.7	46.0	30.6	7.1	.3
2. Balance of the nature is so strong it will repress the damaging consequences the climate changes may occasion	.3	7.7	29.4	38.3	22.0	2.3
3. Disastrous consequences of the climate changes may be avoided by giving up the present way of industrial development	.0	1.1	6.3	31.4	48.9	12.3
4. Man cannot control the changes of climate, therefore he should not give too much attention to the matter	.0	17.7	40.6	20.9	18.9	2.0
5. No human effort or device could stop climate changes from happening	.9	10.3	30.0	30.0	25.4	3.4
6. Science and new technologic solutions will prevent possible damaging effects caused by climate changes	.0	3.7	11.7	43.7	34.9	6.0

TABLE 3

3.	**Do you think that if there were significant changes of climate they would influence the further development of Cres and Losinj islands (Mark only one answer).**	
0.	No answer given	.3
1.	It would have no impact on further development of the islands	4.6
2.	It would not have greater impact on further development of the islands	24.6
3.	I do not know, I cannot make an assessment	20.3
4.	It would have great influence on further development of the islands	44.3
5.	It would completely determine further development of the islands	6.0

TABLE 4

4.	**Give an estimation, please, of the imminence of the cited changes of climate and of the consequences in near future on the islands of Cres and Losinj.**						
1.	Mean air temperature will increase	.6	2.0	18.3	33.4	40.6	5.1
2.	Level of the sea-water will rise	.3	2.3	17.1	39.1	36.9	4.3
3.	Temperature of the sea-water will rise	.3	2.6	17.1	37.4	38.3	4.3
4.	High tide waves will come on	.3	5.7	23.1	50.3	18.9	1.7
5.	Frequency of storms will increase	.0	3.4	20.9	46.0	27.1	2.3
6.	Frequency and length of dry seasons will increase	.0	1.1	13.7	33.4	47.4	4.3
7.	Frequency and length of rainy seasons will increase	.6	2.3	19.7	38.3	34.9	4.3
8.	Features of seasons will change	.6	.3	6.6	16.9	57.4	18.3
9.	There will be greater emigration movements of the inhabitants of the narrow coastal area towards inland	.0	17.1	39.7	28.6	13.1	1.4
10.	There will be greater emigration movements of the islanders towards the continent	.3	14.3	40.6	28.9	14.6	1.4
11.	Health problems will increase	.3	.9	12.9	27.4	42.6	16.0
12.	Flora and fauna of the island will undergo changes	.0	2.9	16.9	27.1	43.1	10.0

TABLE 5

5.	**Some possibilities of preventing and alleviating the eventual negative consequences of the changes of climate. Make an assessment, please, of each and say when they should be applied.**						
1.	Building protection walls and embankments in order to alleviate the consequences of the rise of sea-water level	.0	41.7	24.3	8.0	1.1	24.9
2.	Withdrawing the working permission to the industrial plants whose work adds to the causes of changes of climate	.0	8.6	14.0	61.1	3.4	12.9
3.	Bringing stricter laws regarding environmental pollution	.0	2.6	7.7	78.3	1.4	10.0
4.	Changing from the use of fossil fuels (coal, oil, gas) to the use of new renewable fuel resources (wind, sun, waves)	.0	3.4	8.9	69.1	1.4	17.1
5.	Obligation to build in catalyzing filter devices for industrial waste gases	.3	4.6	6.3	76.0	1.7	11.1
6.	Bringing stricter laws to prohibit new construction building in narrow coastal area	.0	5.7	8.3	66.0	1.4	18.6
7.	Adapting economy development plans to new knowledge on eventual consequences of changes of climate	.9	1.4	10.0	64.6	.6	22.6
8.	Intensifying reforesting of the islands	.3	21.4	12.3	56.9	.6	8.6

TABLE 6

6.	**Make an estimation of how upsetting the following problems are for the life of inhabitants on Cres and Losinj islands.**					
1.	Industrial waste pollution of the sea-waters	.0	36.6	38.3	23.7	1.4
2.	Crashes of the ships transporting dangerous loads (chemicals, oil etc.)	.0	30.0	31.4	36.0	2.6
3.	Damage of the ozone layer	.3	15.1	23.4	42.0	19.1
4.	Accidents in nuclear power plants	.9	26.0	26.6	35.4	11.1
5.	Air pollution from industrial sources	.3	47.1	25.4	25.1	2.0
6.	Air pollution from traffic fumes	.0	56.3	28.9	13.1	1.7
7.	Pollution of foodstuffs (by pesticides and the like)	.6	41.1	32.9	23.4	2.0
8.	Pollution of drinking water	.0	54.0	18.6	25.4	2.0
9.	Sudden changes of the climate	.9	30.3	35.4	26.3	7.1
10.	Disappearance of several sea and land fauna species	.0	23.7	32.9	33.4	10.0
11.	Natural catastrophes (earthquakes, long dry seasons, hurricanes and the like)	.0	33.7	33.1	24.6	8.6
12.	Non-organized waste dumps	.0	24.0	22.0	50.9	3.1
13.	Forest fires on the islands	.3	22.9	23.4	51.7	1.7
14.	Lack of drinking water	.3	51.4	22.9	24.9	.6
15.	Decrease of number of islands inhabitants	.0	29.1	36.9	31.1	2.6
16.	Bad tourist seasons	.9	7.4	25.7	64.9	1.1
17.	Increased settling of the inhabitants not born on the islands	.9	42.6	29.4	23.4	3.7
18.	Neglecting the development of the inland settlements	.0	16.9	41.1	36.9	5.1
19.	Disappearance of the particular way of life on the islands	.3	15.1	36.0	42.9	5.7

TABLE 7

7.	Did you personally notice some of the following changes on the islands of Cres and Losinj these last decades?	No answer	No	Yes
1.	Are some fauna and flora species decreasing in number or disappearing?	.3	38.3	61.4
2.	Are there changes in frequency and quantity of precipitations?	.3	23.7	76.0
3.	Are there changes in frequency and length of dry seasons?	.3	24.6	75.1
4.	Are there changes in directions and strength of winds?	.3	65.7	34.0
5.	Are there changes in features of seasons?	.3	21.1	78.6
6.	Are there changes in level of tides?	.6	70.3	29.1
7.	Are some up-to-now rare natural phenomenons becoming any more frequent ("blossoming of the sea", "invasion of jelly-fish" etc.)	.3	20.9	78.9
8.	The bottom of the sea and the features of the bottom are changing	.9	60.3	38.9
9.	The coast area is crumbling off and sandy bays are becoming smaller	.9	80.9	18.3
10.	Some smaller islands and rocks have been overflown	1.1	94.9	4.0
11.	Fishing catch is diminishing	.3	17.7	82.0
12.	Agricultural cultures yields are diminishing	.6	36.0	63.4

TABLE 8

8.	Have you been informed of different forecasts regarding changes of climate?	
1.	I have not been informed	46.6
2.	I have been partly informed	48.0
3.	I have been well informed	5.4

TABLE 9

9.	Would you like to learn more on the problems?	
1.	No, I am not interested	22.6
2.	Yes, I would like to learn more	70.6
3.	I think I know enough already	6.9

TABLE 10

10.	Sex of the examined person:	
1.	Male	49.7
2.	Female	50.3

TABLE 11

11.	Age of the examined person:	
1.	Up to 25	9.4
2.	From 26 to 35	20.3
3.	From 36 to 45	21.4
4.	From 46 to 55	12.3
5.	From 56 to 65	13.4
6.	Over 66	23.1

TABLE 12

12.	Level of the education:	
0.	No answer given	.6
1.	Not schooled	6.0
2.	Finished up to 8th grade	31.1
3.	High school	47.1
4.	University or faculty	14.9
5.	Master degree or Doctorate	.3

TABLE 13

13.	**Profession of the examined person:**	
0.	No answer given	.3
1.	Farmers - workers in agriculture	4.6
2.	Workers in material production	7.1
3.	Workers not in material production	14.3
4.	Employees in offices	8.3
5.	Experts, artists, general practitioner	9.4
6.	Private craftsmen	8.3
7.	Civil service and guard employees (MIA, CA, fireman brigades etc.)	1.1
8.	Pupils and students	1.1
9.	Housewives	18.9
10.	Pensioners	16.3
11.	Unemployed	4.3
12.	Fishermen	2.0
13.	Sailors	4.0

TABLE 14

14.	**Examined person employed:**	
1.	Unemployed	5.1
2.	Housewife, pensioner	35.7
3.	Pupil, student	1.1
4.	In agriculture or forestry	4.9
5.	Fishing industry	2.6
6.	Industry, mining, construction-building	7.1
7.	Traffic, navigation	6.9
8.	Trading	4.3
9.	Catering, tourism	13.7
10.	Crafts	1.7
11.	Public works	3.7
12.	Education, culture	5.4
13.	Health service, social security	3.1
14.	Government offices, political organizations and the like	4.6

TABLE 15

15.	**What was the family income last month (in May, in Croatian dinars)?**	
0.	No answer given	1.7
1.	Up to 15.000 HRD	34.6
2.	15.001 to 25.000 HRD	31.4
3.	25.001 to 35.000 HRD	14.3
4.	35.001 to 45.000 HRD	9.4
5.	45.001 to 55.000 HRD	3.1
6.	55.001 to 65.000 HRD	2.3
7.	Over 65.000 HRD	3.1

TABLE 16

16.	The settlement the examined person was born in:	
0.	No answer given	.3
1.	Country settlement	49.4
2.	Mixed settlement	14.0
3.	Town settlement	36.3

TABLE 17

17.	How long have you been living on the island?	
1.	Less than 10 years	11.1
2.	From 10 to 19 years	12.3
3.	From 20 to 29 years	10.9
4.	From 30 to 39 years	7.7
5.	From 40 to 50 years	2.6
6.	More than 50 years	1.4
7.	Born on the island	54.0

TABLE 18

18.	Type of settlement:	
1.	Urban centre	50.0
2.	Local centre	34.6
3.	Rural settlement	15.4

APPENDIX II

STATIONS USED IN SCENARIO CONSTRUCTION FOR THE NORTHERN ADRIATIC

Note that not all these stations will necessarily be used in the final scenario construction. They must first fulfill the criteria for acceptance laid down in Section 2 of this report, and in the Final Report.

ITALY

STATION	E	N	HT	PRN	TEM	P%	T%
1. BASTIA	9.4	42.7	n/a	1961-1985	1961-1985	100	100
2. TRENTO	11.1	46.1	312	1951-1976	-	100	0
3. UDINE	13.2	46.0	92	1967-1989	1967-1980	93	95
4. MILANO	9.2	45.5	103	1951-1987	1951-1986	95	99
5. VERONA	10.9	45.4	67	1961-1989	1961-1985	98	97
6. PADUA	12.0	45.4	13	1951-1974	-	100	0
7. VENEZIA	12.4	45.4	17	1951-1989	1951-1988	98	100
8. TRIESTE	13.8	45.7	20	1951-1989	1951-1988	98	100
9. PARMA	10.3	44.8	56	1951-1977	1951-1976	100	100
10. BOLOGNA	11.5	44.5	60	1951-1974	1961-1970	100	100
11. PISA	10.4	43.7	2	1961-1989	1961-1980	97	100
12. FLORENCE	11.3	43.8	75	1951-1977	1951-1970	100	100
13. ANCONA	13.5	43.6	104	1951-1978	1951-1978	98	98
14. PESCARA	14.2	42.4	9	1961-1989	1961-1980	97	100
15. ROME	12.2	41.8	2	1951-1989	1951-1988	98	99
16. NAPOLI	14.3	40.9	88	1961-1987	1961-1987	99	99
17. BRINDISI	18.0	40.7	15	1961-1989	1961-1980	98	100
18. MARINA	16.9	40.4	12	1967-1989	1967-1980	96	95
19. AVEZZANO	13.6	42.0	n/a	1951-1970	-	100	0
20. BOLZANO	11.3	45.5	241	1961-1985	1961-1985	99	91
21. GROSSETO	11.1	42.8	5	1961-1985	1961-1985	99	100
22. PERUGIA	12.5	43.1	208	-	1961-1985	0	98
23. FALCONARA	13.4	43.6	12	-	1961-1985	0	97
24. CAMPOBASSO	14.7	41.6	793	1961-1985	1961-1985	99	99
25. BARI	16.8	41.1	34	-	1961-1985	0	99
26. POTENZA	15.8	40.6	823	1961-1985	1961-1973	99	96

CROATIA AND PART OF BOSNIA AND HERZEGOVINA

STATION	E	N	HT	PRN	TEM	P%	T%
27. PULA	13.9	44.9	30	1951-1980	1951-1980	100	100
28. ZADAR	15.2	44.1	1	1951-1980	1951-1980	100	100
29. HVAR	16.4	43.2	20	1951-1980	1951-1980	100	100
30. VARAŽDIN	16.4	46.3	169	1951-1980	1951-1980	100	100
31. DARUVAR	17.2	45.6	161	1951-1980	1951-1980	100	100
32. BANJA-LUKA	17.2	44.8	160	1951-1980	1951-1980	100	100
33. BUGONJO	17.5	44.1	562	1951-1980	1951-1980	100	100
34. MOSTAR	17.8	43.4	99	1951-1980	1951-1980	100	100
35. TUZLA	18.7	44.6	305	1951-1980	1951-1980	100	100
36. ZAGREB	16.0	45.8	163	1951-1989	1951 1988	98	99
37. SISAK	16.4	45.5	98	1951-1970	1951-1970	100	100
38. SPLIT	16.4	43.5	129	1951-1989	1951-1988	98	99
39. LIVNO	17.0	43.8	730	1951-1970	1951-1970	100	100
40. SARAJEVO	18.4	43.9	637	1951-1989	1951-1988	97	99
41. PARG	14.6	45.6	863	1961-1990	1961-1990	100	100
42. RIJEKA	14.5	45.3	104	1961-1990	1961-1990	100	100
43. PAZIN	13.9	45.2	291	1961-1990	1961-1990	100	100
44. OGULIN	15.2	45.3	325	1951-1990	1951-1990	100	100
45. CRIKVENICA	14.7	45.2	2	1961-1990	1961-1990	99	98
46. ROVINJ	13.7	45.1	5	1951-1990	1951-1990	95	95
47. SENJ	14.9	45.0	26	1961-1990	1961-1990	100	100
48. CRES	14.4	45.0	10	1961-1990	1961-1990	100	100
49. ZAVIŽAN	15.0	44.8	1594	1961-1990	1961-1990	100	100
50. RAB	14.8	44.8	24	1961-1990	1961-1990	100	100
51. PAG	15.1	44.5	3	1961-1990	1961-1990	99	98
52. GOSPIĆ	15.4	44.6	565	1961-1990	1961-1990	100	100
53. MALI-LOŠINJ	14.5	44.5	53	1961-1990	1961-1990	100	100
54. SILBA	14.7	44.4	20	1961-1990	1961-1990	97	96
55. KNIN	16.2	44.0	234	1961-1990	1961-1990	100	100
56. ŠIBENIK	15.9	43.7	77	1961-1990	1961-1990	100	100
57. PALAGRUZA	16.3	42.4	88	1961-1990	1961-1990	91	100

E - latitude
N - longitude
HT - height above sea level (m)
PRN - length of precipitation record
TEM - length of temperature record
P% - percentage of precipitation record present
T% - percentage of temperature record present

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