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CONTRIBUTION TO THE KNOWLEDGE OF THE OCEANOGRAPHIC SEA FEATURES IN THE SOUTH KORNATI - THE ŽIRJE ISLAND AREA

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Due to its geographic position, geomorphology and certain signs of frequent occurrences of atypical conditions, the south area of the southern part of the Kornati islands and the island of Žirje is very interesting for the thermohaline analysis. The analysis has not been completed, however, the activities necessary for getting an insight into justifiability and the need for radical interventions have been made. On the basis of the data obtained from longtime measurements, separate analyses of the sea water temperature, salinity and density have been made, defining annual courses of mean monthly and extreme values, mean monthly values at characteristic depths, and vertical distribution of mean monthly values. Special importance was given to external and internal influences.

Key words: unit, process, thermohaline conditions, gradient

Zbog zemljopisnog položaja, geomorfologije i stanovitih naznaka o čestim pojavama netipičnih stanja, područje južno od južnih Kornata i otoka Žirja nametnulo se vrlo zanimljivim za termohalinsku analizu. Analiza je potpuna, već se obavilo radnje potrebne za dobivanje uvida u opravdanost i potrebu temeljitih zahvata. Temeljem podataka koje se dobilo dugogodišnjim mjerenjima pristupilo se odvojenim raščlambama vrijednosti temperature, slanosti i gustoće morske vode na način da se odredilo godišnje hodove srednjih mjesečnih i ekstremnih vrijednosti, srednjih mjesečnih vrijednosti na karakterističnim dubinama i okomitog rasporeda srednjih mjesečnih vrijednosti. Potrebito značenje dalo se vanjskim i unutarnjim utjecajima.

Ključne riječi: jedinica, proces, termohalinska stanja , gradijent

Introduction

On the basis of the existing data of parameters: temperature, salinity and density of the sea water in the aquatorium south of the Kornati islands and the isalnd of Žirje, it is possible to determine (*define)* thermohaline relationships and processes developing at sea. The data were obtained from longtime measurements, so that their mean values, the lowest and the highest ones (*extreme),* seasonal, annual and the ones lasting for several air surface temperature, show the real thermohaline conditions in the researched area of the open part of the Middle Adriatic.

The aim of this work is a radical analysis of the values of thermohaline units (*parameters)* in the water column, the establishment of important inter-relations with the values of climatic elements, dynamics of sea water and defining of intensity of other connections and conditions with some other physical and chemical parameters.

Researched area and materials

Complicated researches of the Adriatic began in 1011 and happened to be more intensive after 1948. In this work the period from 1982 to 1987 was emphasized where the greater part of the data was collected by research ships. The aquatorium explaining the data and analyzing the sea water thermohaline structure was defined according to the internal division of the Croatian Hydrographic Institute of the Adriatic (Marine chart 100). The area is run after the working sign 67-A/67-B. It is situated south from the southern part of the Kornati islands and the island of Žirje (Fig. 1), and bordered by the connecting points: 1 - island Piškera, 2 - island Žirje, 3 - φ=43°22,0'N λ=15°14,0'E, 4 - φ=43°30'Nλ=15°20,0'E and 5-φ=43°36,5'N λ=15°12,0'E.

The mentioned aquatorium was chosen due to its geografical position resulting in numerous characteristics (A.T. Ippen, 1966) interesting for oceanographic scientific researches. Firstly, the area covers the most intensive entrance to the northwestern Adriatic sea current. It is in the open sea and exposed to the direct maritime influences. It is crossed by isobaths of 100 and 200 m. From north to south the depth suddenly increases to more than 200 m, and slightly decreases in more southern areas. The biggest measured depth was 214 m, southwest of the lighthouse Blitvenica (Fig. 1).

Very important climatic influences on this area are extremely intensive and manifold. Warmer and more humid air masses come from the southern, and colder and dry ones from the northern quadrants. The influence of cold bora (north-eastern wind) on that area is especially significant, respectively on the values of the sea water surface temperature. It causes a number of other processes (inversions, convections and the like).

A total of 9000 data were used in analyzing all three parameters. They were obtained from approximately 200 measurements at standard oceanographic depths. It was measured at five stations within the area.

The thermal values were measured by reversible thermometer until 1978 *Richetr Wirsse,* and later by CSTD sounding pipe. The accuracy in measurement is 0,01°C. Besides, the temperature was measured by bathythermographs *Neil Brown* (accuracy in temperature reading is 0,1°C, and in depth 0,5 m). The surface temperature was measured during bathythermographic measurement by surface thermometer.

Until 1978 the salinity from the sea water samples was defined by laboratory oscillation. Later on, by laboratory salinometer and CSTD sounding pipe (accuracy 0,02ppt). The samples of sea water were collected by Nansen and Niskin pipes.

Sea water density was measured from thermal and haline values by experienced Knudsen-Ekman equation. By agreed decision it is presented in oceanography as σt value:

$$\sigma t = \rho - 1000 \text{ (kg/m3)}$$

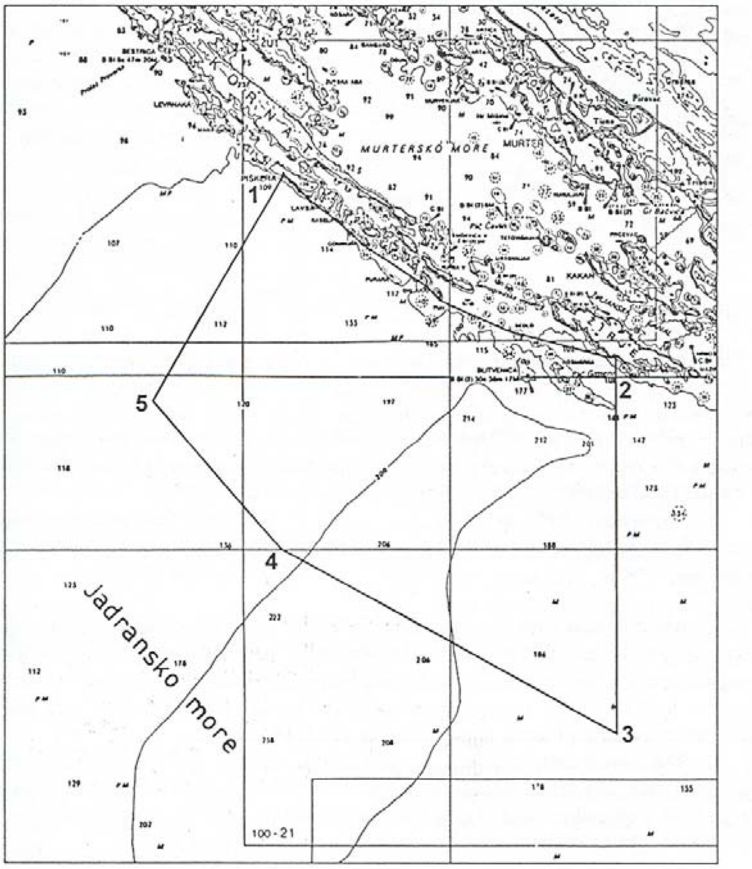

Fig. 1 Researched area (Marine chart 300-32)
Sl. 1. Istraživano područje (Pomorski zemljovid 300-32)

Temperature

The Adriatic belongs to the seas of *anothermal* water type. It is characterized by the direction of vertical gradient, from the surface towards the bottom. Generally, the sea water dynamics is mostly influenced by the thermal distribution, then fresh-water inflows, air temperature (wind) and less by precipitation.

In spring the thermocline starts to develop in the water column (sudden increase of thermal values). It develops gradually increasing its intensity. It is the biggest in summer. Later on the thermocline sinks, its intensity is reduced and by the end of autumn it disappears. Isometry arises in the water column, namely, the thermohaline homogeneity.

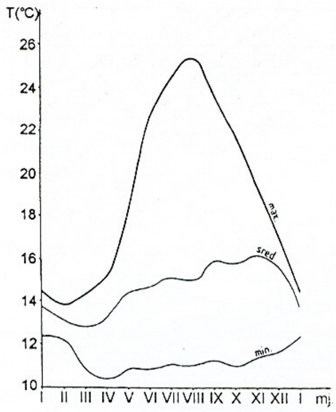

Fig. 2 Annual course of mean monthly and extreme values of the sea water temperature

Sl. 2. Godišnji hod srednjih mjesečnih i ekstremnih vrijednosti temperatura mora

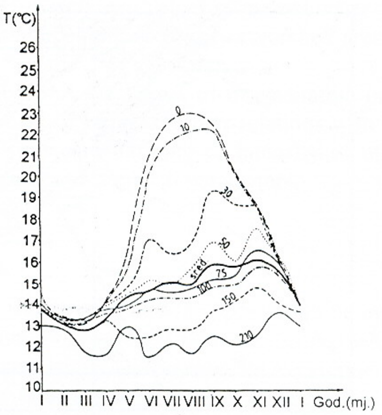

Fig. 3 - Annual course of mean monthly temperature values of the sea water at characteristic depths

Sl. 3. Godišnji hod srednjih mjesečnih vrijednosti temperature morske vode na karakterističnim dubinama

Mean annual temperatures in the researched area (Fig. 2) show certain regularity in changes, even though there are some, seemingly unusual exceptions to the generally accepted opinion that the sea is the warmest in summer and the coldest in winter. In the diagram in the Figure 2 mean data values have been used for the whole area and in the whole water column (namely, data for water mass, tab. 1).

The lowest mean temperature is in March, 12,78°C, and it increases significantly until May and July, then it decreases for 0,14°C in August. The greatest increase is reached till September, and the annual maximum of 16,17°C is in November. From December till January the temperature suddenly decreases for 1,89°C.

Tab. 1 - Mean monthly and extreme values of the sea water temperature (HHI database)

month	average	min	max
I	13,72	12,32	14,46
II	13,08	12,21	13,80
III	12,78	10,80	14,30
IV	13,27	10,40	15,14
V	14,35	10,87	18,03
VI	14,62	10,87	22,42
VII	15,08	11,08	24,42
VIII	14,94	11,05	25,40
IX	15,89	11,25	23,70
X	15,75	10,98	21,84
XI	16,17	11,34	19,44
XII	15,61	11,66	17,09

It is interesting that the temperatures in March are lower than the ones in January and the values in February. The causes lie in external and internal factors and especially in the sea water dynamics, namely, advectional influence from the Mediterranean. The geographic position has a great importance as well and the exposure to the the cold winds impact from the north quadrants. The very frequent wind bora appears in this area in March with all its climatic characteristics.

The highest temperature value was measured on August 1, 1960, 25'40°C, and the lowest on April 14, 1948, 10,40°C .The diagram showing the mean monthly values of the sea water temperature at characteristic depths (Fig. 3) could be used in presenting the annual characteristics of the water column thermal structure. The following depths were chosen: 0, 10, 30, 50, 75, 100, 150 and 210 m.

Tab. 2 - Mean monthly values of temperature in the water column (HHI database)

D	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	13,75	13,02	13,03	14,29	16,46	20,94	22,60	22,99	22,48	20,26	18,69	16,05
5	13,84	13,01	13,01	14,31	16,04	20,42	22,15	22,16	22,24	20,22	18,66	16,05
10	13,82	13,04	13,17	14,31	15,75	20,06	21,64	22,09	22,18	20,17	18,63	16,10
15	13,50	13,40						21,51				
20	13,77	13,06	13,22	14,15	15,40	18,46	18,54	18,36	20.49	19,81	18,61	16,28
30	13,86	13,22	13,40	14,14	14,80	17,07	16,43	16,86	19,28	18,65	18,58	16,25
33								...			18,93	
34										19,32		
36											18,38	
37										18,46		
40			12,85		14,58			15,87			18,16	
44												15,76
45												16,82
49							15,50					
50	13,73	13,29	13,36	13,95	14,46	15,15	14,99	15,75	16,92	16,08	17,52	16,34
60					14,24							
63						14,69						
65						14,71						
66												15,56
67						14,69						
70	13,55	13,48	12,92									
74							14,86					
75	14,02	13,25	13,32	13,74	13,95	14,65	14,56	14,72	15,22	15,36	16,54	16,13
85											17,82	
88												15,66
93									14,60			
94			12,90									
98							14,59					
100	14,04	13,41	13,24	13,55	13,79	14,19	14,28	14,31	14,81	14,95	15,72	15,41
105						14.13						
107							13,98					
125												14,86
133												15,61
140			12,84									
148							12,58					
150	13,63	13,38	12,76	13,26	12,41	12,48	12,80	12,79	13,70	14,14	14,79	13,99
157											13,94	
158											14,13	
165										12,64	13,05	
170											12,48	
175											12,21	
178												14,95
180										11,65		
190								11,65				
195				12,90								
210	12,97	12,86	11,77,	11,68	12,92	11,54	12,11	11,68	12,51	12,06	12,48	13,65

Interlaces of thermal curves on the left and on the right side of the diagram (or approximate values), in the period from December till April show the isothermal condition in the water column. In such cases the complete analysis could be made only in the diagrams of vertical distribution of the values.

Stratification of water column starts in April. It is shown on the diagram in the differences of the thermal values at particular depths. In the period of stratification the surface temperature is the highest and it is reduced towards the bottom (Tab. 2). The water column is statically stable and advection movement develops mostly. There are no impulses for convection movement, except in April and May at the depth of 150 and 210 m (Fig. 3). Dislocation appeared in the form of thermal inversion at that layer, so that the water above the warm layer is a little bit colder. The stability in the water column is established by the local convection movement.

In the late autumn and winter period the isothermal condition (nearly) governs the water column, and the appearance of warmer water at greater depths is the consequence of vertical interference established by static balance. At that time the surface water cooled by the influence of cold winds and the low air temperature, goes to the bottom, mixes with the surrounding one, taking in the water column the position corresponding to its specific density, namely, weight.

Analyzing the vertical distribution of the temperature values it is possible to define the thermal relationships in the water column and the degree of stratification development, namely, the beginning and duration of isothermia. The vertical distribution of mean monthly sea water temperature values have been shown on the Fig. 4. By comparing the curves, the thermal changes in annual period have been noticed. Isothermia dominates in the whole water column in winter.

Smaller aberrations have been emphasized more on the diagram due to the choice of measures at abscissa. Temperatures in January are generally higher, they are close at the depth of about 100 m in February and March, and the bottom water is colder in March in relation to February for 1,09°C (Tab. 2).

In April the water column is statically stable, and in May the stability is still increased, with the disturbance thickness of circa 60 m at the bottom layer. The outfit the curve predicts the forthcoming stratification in June. The surface temperature is reduced from the surface to 50 m of depth in June (0,12 °C/m). This is a weak surface termocline *(According to the generally accepted measures in oceanography, under the weak thermocline it is understood the one with the gradient up to 0,30°C/m, the moderate one with the gradient from 0,40 to 1,00°C/m, and the strong one is higher).*

In summer, termal gradient increases, it is about 0,50 °C/m, and there is termocline at the 15-25 m depth. Consequently, it was lowered from the surface to the greater depth and as regards the condition in June, the intensity was increased. It is manifold and more intensive towards the bottom. At the depth of ca 150 m it is positive and it is the greatest in August (circa 1,40 °C/m), at the depth of about 15 m. It is deeper in September and its intensity is reduced (Fig. 4).

In autumn the surface temperature gradually decreases (tab. 2, fig. 4). In October and November weak positive thermoclines between 30 and 40 m of depth were registered, and bouncing positive/negative changes to the bottom. These changes (especially in November) are the signs of termination in the water column stratification. The similar thing happens in December, but such a distribution is closer to the isothermic one.

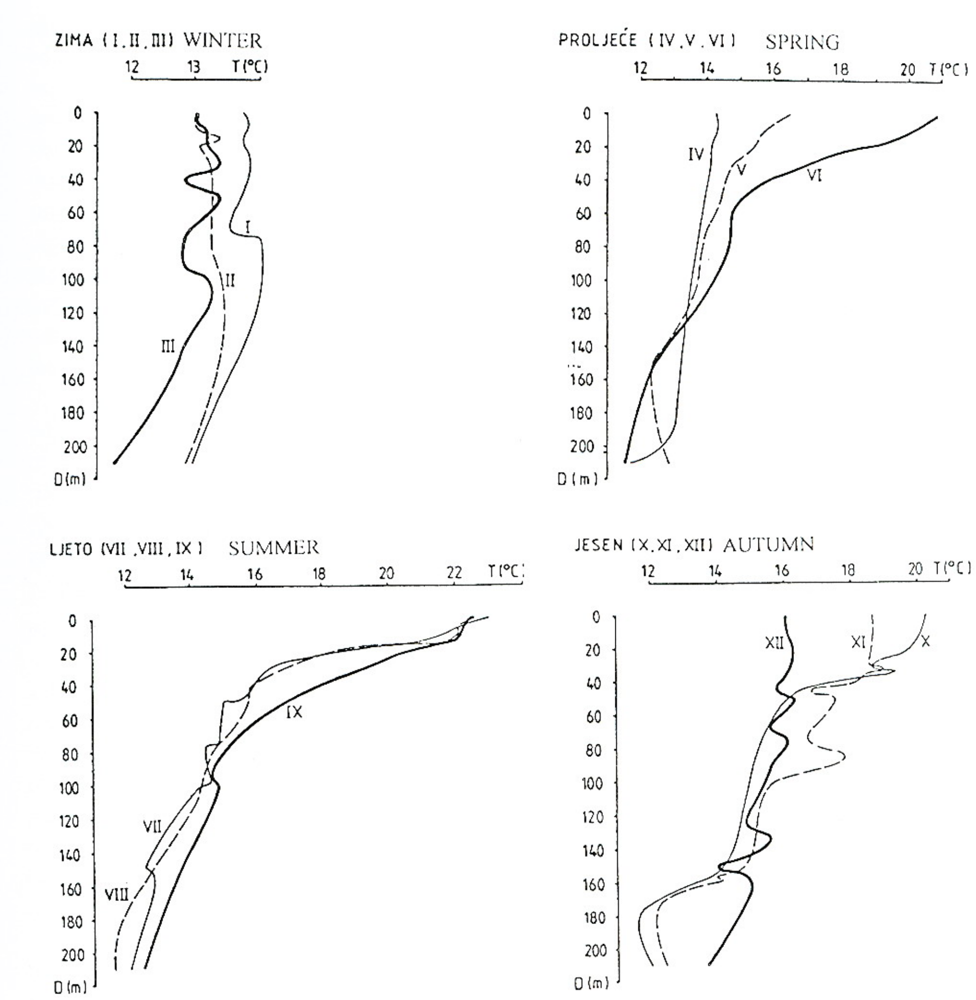

Fig. 4 Vertical distribution of mean monthly sea water temperature values
Sl. 4. Okomiti raspored srednjih mjesečnih vrijednosti temperature morske vode

Salinity

On the basis of the knowledge about permanent quantitative inter-relations of ions *macroconstituents* in sea water, the degree of sea water salinity is defined. As the measure for the quantity of other ions or for defining the total quantity of salt in the volume unit, the ion of any macroconstituent can be used. In practice, it is realized through *chlorine-ion* determination as it is mostly represented in sea water. The measuring value is called *chlorinity.* The ratio between salinity and chlorinity is:

$$S(ppt) = 1,8050Cl + 0,03$$

1,8050 - chloride coefficient; 0,03 - carbonsulfate coefficient

The importance in knowing the sea water salinity consists in its role to maintain the balance between the physical and biochemical condition at sea and the possibilities of monitoring and defining the water masses, dynamic convectional, advectional and turbulent movements, dynamics of physical and chemical assimilative and osmoregulating processes etc. (M. F. Maury, 1963). On the basis of the data obtained from longtime mea-surements, it was found out that the mean haline value in the Adriatic was approx. 38,400 ppt. It is slightly lower than the salinity of the East-Meditteranean water, so this one with its inflow in a certain degree salts the Adriatic. The effects of evaporation and hydrologic factor (fresh-water inflow) influence a great deal on haline values and less on the effects of precipitation. In the researched area the oscillations of the mean haline values are rather small (Fig. 5). The greatest values were recorded in the period winter-spring, the beginning of summer and in October and November. The maximum measured annual values also oscillate moderately, whereas the *minimum* oscillations are considerable.

The diagram (Fig. 5) shows three characteristic minimums and maximums. The greatest minimal extreme was recorded in November (38,440ppt, table 3). Accordingly, in the month when the mean monthly values were the greatest. The lowest were in Decem-ber, 36,600ppt. The haline condition at characteristic depths of 0, 10, 30, 50, 75, 100, 150 and 210 m is of peculiar interest. Even the superficial survey reveals considerably lower haline values on the surface layer at the depths of 0 and 10 m. The values mutually deviate less at greater depths so that the curves of annual courses interlace (Fig. 6).

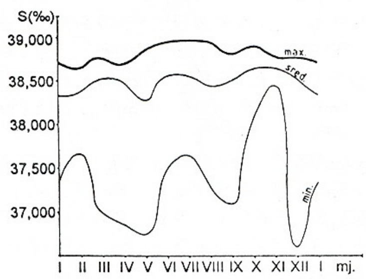

Fig. 5 Annual course of mean monthly and extreme haline values

Sl. 5. Godišnji hod srednjih mjeseč-nih i ekstremnih halinskih vrijednosti

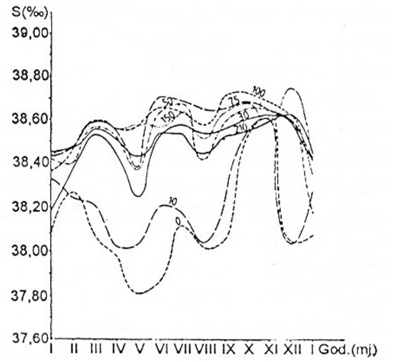

Fig. 6 Annual course of mean monthly haline values at characteristic depths

Sl. .6 Godišnji hod srednjih mjesečnih hali-nskih vrijednosti na karakterist. dubinama

In February the difference in the greatest and lowest salinity in the water column is 0,300ppt. The least salt water is not on the surface but at the depth of 10 m. Consequently, there is a minimum undersurface salinity. The greatest haline value is at the depth of 150 m. It is saltier than the bottom water for only 0,01ppt (table 4). In relation to to the total difference in the water column salinity (0,300ppt), a moderate haline homogeneity was found. It was confirmed by the analysis of the vertical distribution as well. The salinity differences between surface and deeper layers are greatest in May and June, and they are also greater in August, September and December months.

Tab. 3 Mean monthly and extreme values of the sea water salinity (HHI database)

month	average	min	max
I	38,336	37,340	38,720
II	38,375	37,660	38,640
III	38,533	36,980	38,770
IV	38,479	36,857	38,687
V	38,280	36,740	38,864
VI	38,557	37,482	38,930
VII	38,557	37,653	38,960
VIII	38,440	37,300	38,950
IX	38,494	37,087	38,800
X	38,645	38,036	38,890
XI	38,654	38,440	38,785
XII	38,533	36,600	38,764

In winter months the haline values are close in the water column (Fig. 7). Only in January the salinity considerably oscillates from the surface to the depth of circa 100 m. Aberration is particularly evident (value decrease) in the layer between 10 and 20, and 60 and 100 m of depth (Fig. 7). The aberrations are about 1,000ppt and even less (table 4), which implies high values.

The possible cause is a climatic factor. The surface layer, which is warmer and less salt, is cooled under the effects of cold air masses, it condenses and starts moving deeper. Since there are two undersurface minimum salinities in January, it is obvious that the double sinking of less salty sea water surface layer occurred. It is not atypical for this area, especially in January when immediate breakthroughs of cold air masses from the northern quadrants occur, especially in favour of winter characteristics of swampy fields. In the area of the imerged surface water, the salt water inflows by substitute advection from the south Adriatic, namely, the Mediterranean.

In the spring months a less salty surface layer has been observed. It is the period when the water is usually sweetened by the abounding inflow of fresh-water from the rivers (melting of snow) and precipitation, and longitudinal surface circulation in the Adriatic basin changes the direction into the transversal one. In such a way the saltier water inflow from the East Mediterranean has been reduced.

The haline process in the water column going on all the year round was presented on the Fig. 7: stratification, disturbing of stable condition and reconditioning of the haline homogeneous condition. In July, the surface layer (circa 50 m thick) was sweetened. In August, less intensive undersurface minimum salinity was recorded, which is in relation to the one in July generally greater (Tab. 4). The salinity in winter months has approximate values in the entire water column. The exception is the condition in December in the surface layer which is circa 10 m thick, where haline values are decreased for about 0,550 ppt.

Such a condition is not typical for the researched area and for the time of the year. The fresh-water inflow was reduced and the precipitation either, but the advection from the Mediterranean was increased and the inflow of saltier water. The probable reason for this condition are aberrations in the common system of circulation from the ordinary scheme.

Sea water density

Sea water density is the measure depending on the temperature values, salinity and pressure. Under *normal,* it is understood the ratio of the weight of the same volume of the sea, at the temperature of 0,0°C and fresh-water at 4,0°C, at the same pressure.

Tab. 4 Mean monthly haline values in the water column (HHI database)

D(m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	VIII
0	38,08	38,27	38,07	37,98	37,81	37,87	38,12	38,02	38,06	38,53	38,62	38,05
5	38,32	38,18	38,06	37,85	37,93	37,93	38,07	38,15	38,18	38,53	38,63	38,05
10	38,33	38,24	38,21	38,02	38,03	38,21	38,18	38,04	38,26	38,55	38,62	38,04
15	37,58						37,83					
20	38,32	38,35	38,49	38,33	38,22	38,30	38,48	38,26	38,34	38,59	38,62	38,58
30	38,18	38,37	38,53	38,44	38,25	38,53	38,58	38,54	38,57	38,61	38,63	38,61
33											38,67	
34										38,62		
36											38,65	
37										38,63		
40		38,58	38,52		38,26			38,48			38,46	
44												38,62
45											38,63	
49							38,96					
50	38,42	38,40	38,57	38,52	38,37	38,64	38,68	38,42	38,60	38,66	38,65	38,60
60					38,29							
63						38,66						
65						38,68						
66												38,62
67						38,68						
70	37,84		38,49									
74	38,96											
75	38,43	38,48	38,60	38,55	38,38	38,71	38,69	38,65	38,66	38,69	38,65	38,61
85											38,66	
88												38,62
93									38,45			
94			38,55									
98	38,96											
100	38,36	38,46	38,60	38,56	38,58	38,66	38,64	38,58	38,72	38,73	38,69	38,63
105						38,66						
107						38,65						
125												38,64
133												38,62
140			38,55									
148	38,80											
150	38,44	38,48	38,59	38,56	38,58	38,57	38,64	38,52	38,64	38,68	38,76	38,76
157											38,72	
158											38,69	
165										38,63	38,60	
170											38,62	
175											38,59	
178												38,68
180										38,60		
190								38,18				
195				38,55								
210	38,45	38,47	38,56	38,51	38,43	38,54	38,54	38,45	38,53	38,55	38,60	38,63

In this case the density exclusively depends on the salinity. *Real* density (*in situ)* is the ratio of the weight of the sea water volume at the temperature and pressure *in situ* and the volume of pure fresh-water at the temperature of 4,00°C, and the pressure of 0Atm (P. Groen, 1967). It depends on the temperature, salinity and pressure in the sea water (H. U. Sverdrup, 1943):

$$\sigma t = \frac{S X p}{t}$$

In oceanography the density is defined out of haline values (*chlorinity)*, and is directly measured by aerometres, picnometres and in refractometrical way (refraction measuring).

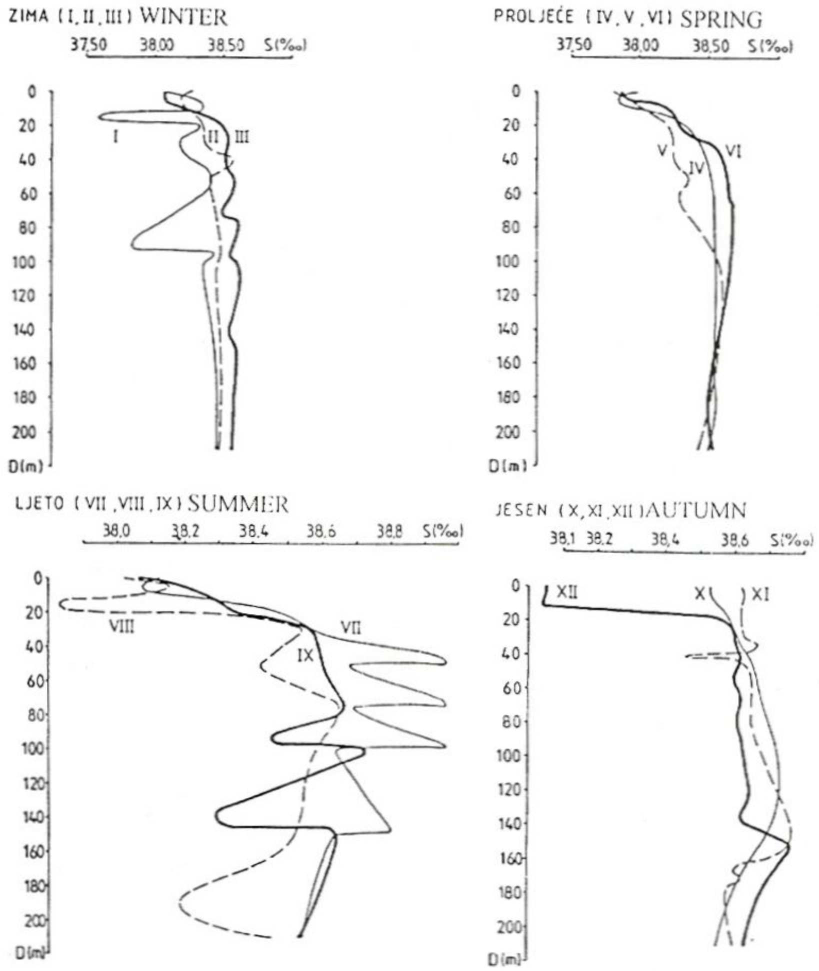

Fig. 7 Vertical distribution of mean monthly haline values
Sl. 7. Okomiti raspored srednjih mjesečnih halinskih vrijednosti

It is given in g/cmł. In practice the unit σt was introduced (SIGMA-t), and it is defined as:

$$\sigma s,t,p = (\sigma s,t,p - 1)\ 10ł$$

If the value $\sigma s,t,p$ = 1,02576, density $\sigma s,t,p$ = 25,75

Sea water density values affect consequently keeping the stable and biochemical condition at sea, its horizontal and vertical distribution directly takes effects in monitoring and movement track determinations, and sources of water masses. The density itself indirectly affects the rhythm of dynamic, physiochemical, assimilative and osmoregulating development processes at sea.

The problem of water masses mixing under the conditions of density values changed by depth is solved by *concept of static stability* (M. Buljan*,* M. Zore-Armanda, 1971). It is based on the fact that, in case the logical arrangement of water masses of different specific weight arises as the result of changing the vertical position in the water column, convection streamings occur. The speed of such reactions is caused by the intensity of the density gradient. The length passed by the water particle depends on the thermohaline properties of the surrounding *fluid*, as it moves vertically to reach the point where its thermohaline properties equalize with the ones from the surrounding water mass. The *compressing and expanding* affect of pressure must not be omitted. The temperature is released from the water particle or it is accepted by the particle itself. That way the surrounding fluid is diluted/condensed, whose density makes possible for the static stability in the water column to be achieved. The thermal effect is less than the compression resulting in static balance. The effect of haline contraction has been left out in the named statement predicting the complex approach to these problems.

In distinction from *absolutely* greatest and mean, absolutely lowest density values (SIGMA-t), as with thermal and haline units, considerably oscillate as regards their mean values. The greatest (28,63) and lowest (24,92) values have been especially obser-ved (Tab. 5). The highest and mean estimated oscillation values are moderate (Fig. 8).

In the summer months the vertical density distribution is normal (Fig. 9), without disturbances. It confirms the conclusions from the temperature analysis and salinity about static stability in the water column. In the values of this parameter significant differences on the surface and at the bottom have been noticed. In August, for example, (differences are the greatest), the density on the surface is 26,24, and at the bottom even 29,35 (table 6). SIGMA-t values at the depth of 10 m do not differ a great deal from the surface (they are greater for 0,40), but at the depth of 30 m from the surface value, they are greater for 2,04. Such a datum can be profitably used in stratification analysis in the water column and in determining the depth layer, namely, water masses expansion.

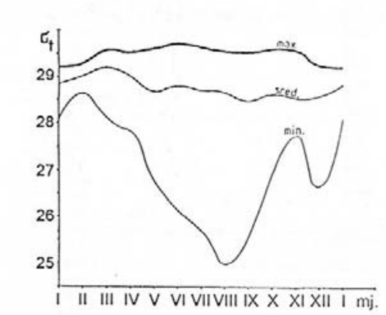

Fig. 8 Annual course of monthly and extreme sea water density values
Sl. 8. Godišnji hod srednjih mjesečnih i ekstremnih vrijednosti gustoće morske vode

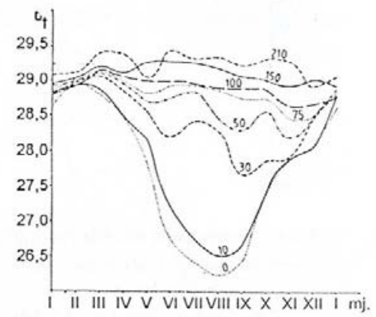

Fig. 9 Annual course of mean monthly sea water density values at characteristic depth
Sl. 9. Srednje mjesečne vrijednosti gustoće u vodenom stupcu (Banka podataka HHI)

Certain homogeneity in the water column develops in January, February and March as well, that means during the winter. The highest degree is achieved in February, when the lowest and highest difference of SIGMA-t value is only 0,20. The disturbances in distribution were recorded in May (inversion at the depth of 150 and 210 m) and less in the period from December until February.

The vertical distribution of SIGMA-t value is shown on the figure 10. The curve for January is of particular interest.

Tab. 5 Mean monthly and extreme sea water density values (HHI database)

month	average	min	max
I	28,84	28,11	29,21
II	29,01	28,63	29,28
III	29,19	28,11	29,57
IV	29,05	27,84	29,53
V	28,67	26,77	29,62
VI	28,81	26,17	29,70
VII	28,71	25,71	29,65
VIII	28,66	24,98	29,55
IX	28,48	25,60	29,54
X	28,62	26,81	29,61
XI	28,54	27,75	29,59
XII	28,57	26,74	29,25

A sudden density decrease has been recorded at the depth of 10 m, from 28,81 (10m) to 28,30. By increasing the depth the density rises
again, so that at 20 m it is 28,82 (Tab. 6). The disturbance has been caused by the influence of climatic factors or by advectional conveyance of denser surface water from some neighbouring area, which repressed the diluted one into the undersurface layer. Due to small depth and small water mass, the static balance is very quickly reconditioned.

Water layer of smaller density has been recorded at the depth of 70 m. In the entire water column the density in March is generally higher in relation to the first winter months, except on the very surface layer. The start of the gradual stratification process of the water column was observed in spring (Fig. 10). In comparison with winter, the surface values are lower from April until June. The process develops gradually, so that the density in June has the lowest spring value of 26,73.

Stratification in the summer months reached its highest degree, and in late autumn SIGMA-t homogeneity sets in. The curve for October (Fig. 10) shows the beginning of vertical water mass mixing, and the process is completed in December. SIGMA-t condition develops in the water column with small aberration values, but the picnoclines, characteristic for the summer time, have not been noticed. Such disturbances are very rare in winter and indicate atypical and short-term conditions.

Conclusion

Mean annual temperatures in the researched area show certain regularity in changes, though there are some, seemingly unusual exceptions from the generally accepted opinion that the sea is warmest in summer and coldest in winter. The lowest mean temperature is in March (12,78°C), and in November the annual max. is 16,17°C. It is interesting that the temperatures in March are lower than the ones in January and the values in February. The reasons lie in external and internal factors and particularly in the sea water dynamics, namely, advectional influence from the Mediterranean. The geographic position has an important function and the exposure to the influence of cold winds from the northern quadrants. A very frequent wind in March is bora with its side effects.

The highest temperature value was measured on August 1, 1960, 25,40°C, and the lowest on April 14, 1948, 10,40°C. Mean haline value in the Adriatic is circa 38,400ppt. It is a little lower than the East-Mediterranean water salinity, so this one, due to its inflow at a certain degree salts the Adriatic. The effects of evaporation and hydrologic factor greatly affect haline values, and less the effects of precipitation.

Tab. 6 - Mean monthly density values in the water column (HHI database)

D(m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
0	28,64	28,94	28,78	28,44	27,83	26,73	26,42	26,24	26,43	27,40	27,89	28,10
5	28,81	28,87	28,78	28,34	28,02	26,89	26,51	26,64	26,58	27,41	27,90	28,09
10	28,81	28,92	28,86	28,46	28,16	27,20	26,75	26,51	26,66	27,43	27,90	28,08
15	28,30							26,52				
20	28,82	29,00	29,07	28,77	28,38	27,69	27,81	27,69	27,18	27,56	27,91	28,45
30	28,82	28,98	29,06	28,83	28,55	28,22	28,42	28,28	27,68	27,88	27,92	28,48
33											27,86	
34										27,72		
36											27,99	
37										27,96		
40			29,17		28,60			28,47			27,90	
44												28,60
45											28,36	
49							28,93					
50	28,91	28,99	29,10	28,94	28,69	28,76	28,83	28,45	28,30	28,56	28,20	28,45
60					28,69							
63						28,88						
65						28,89						
66												28,65
67						28,89						
70	28,50		29,13									
74							29,07					
75	28,85	29,03	29,13	29,00	28,82	28,93	28,93	28,87	28,76	28,75	28,48	28,51
85											28,14	
88												28,63
93									28,74			
94			29,18									
98							29,14					
100	28,79	29,01	29,15	29,05	29,00	28,99	28,96	28,90	28,90	28,88	28,66	28,69
105						29,00						
107						29,03						
125												28,83
133												28,64
140			29,19									
148							29,44					
150	28,95	29,04	29,24	29,12	29,28	29,29	29,27	29,18	29,08	29,02	28,94	29,03
157											29,09	
158											29,03	
165										29,30	29,18	
170											29,32	
175											29,35	
178												28,84
160										29,47		
190								29,14				
195				29,18								
210	29,09	29,12	29,41	29,39	29,06	29,44	29,33	29,35	29,24	29,34	29,30	28,94

In the researched area mean haline disturbance values are not so great. The highest values were recorded through winter - spring time, the beginning of summer and in October and November. The highest measured annual values moderately oscillate as well, but the *minimum* disturbances are significant. Twofold sinking of less salty surface water was recorded in January. It is typical for this area, especially in January when sudden penetrations of cold air from northern quadrants occur. In the area of sunken surface water, saltier water inflows by substitute advection from the south Adriatic, namely, the Meditteranean.

In December, decrease in haline values of ca 0,550ppt was recorded on the surface layer approx. 10 m deep. Such a condition is atypical for the researched area and for the time of the year. Fresh-water inflow and precipitation were reduced, but the advection from the Meditteranean and inflow of salt water were increased. Possible reason for this condition are common current system aberrations from the usual scheme. Sea water density values affect consequently keeping stable and biochemical condition at sea, and its horizontal and vertical distribution directly affects monitoring and determining of movements, and water masses origin. Density in itself indirectly influences the rhythm of dynamic, physiochemical, assimilative and osmoregulating development processes at sea. SIGMA-t values are the result of thermohaline conditions in sea water and the direct consequence of their oscillations.

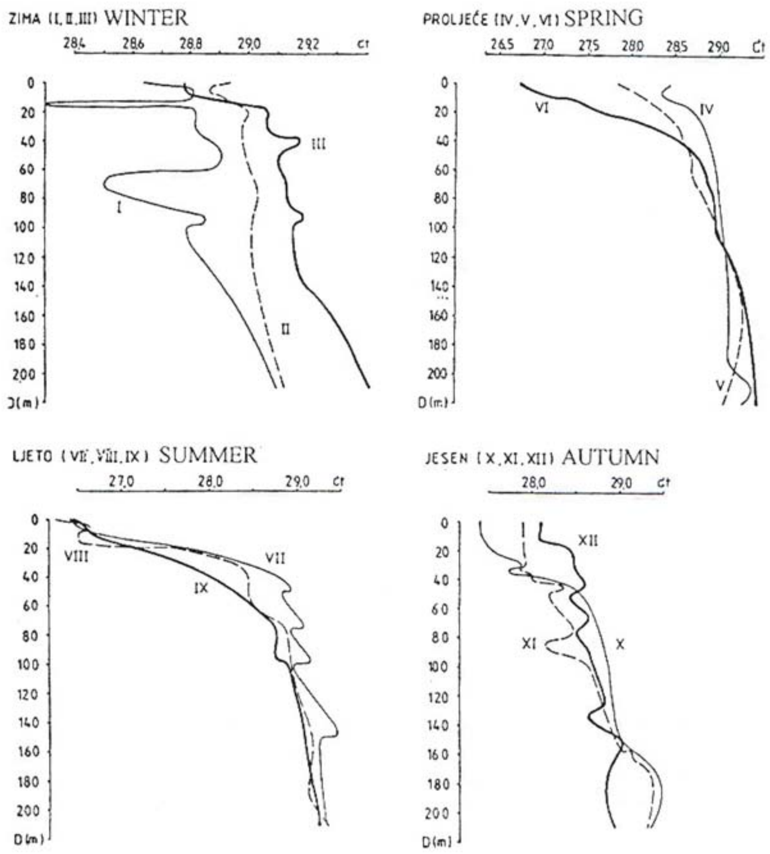

Fig. 10 Vertical distribution of mean monthly sea water density values
Sl. 10. Okomiti raspored srednjih mjesečnih vrijednosti gustoće morske vode

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SAŽETAK:

Z. Bićanić, T. Baković: Prilog poznavanju fizičkooceanografskih svojstava mora u području Južni Kornati - otok Žirje.

Analize termohalinskih uvjeta u moru promatranog prostora Južni Kornati - otok Žirje, zasnivaju se na podacima dobivenim dugotrajnim mjerenjima. Korišten je veći broj podataka, pri čemu vremenski sljedovi zadovoljavaju uobičajene standarde u oceanografiji. Termohalinske analize uključuju analize podataka temperatura, slanoće i gustoće mora. Metodološki pristup nudi nekoliko alternativa. U ovom radu su za svaki od tri parametra odabrane analize godišnjih kretanja srednjih mjesečnih i ekstremnih vrijednosti, godišnjih kretanja srednjih mjesečnih vrijednosti na karakterističnim dubinama i vetikalne distribucije srednjih mjesečnih vrijednosti. Zbog malih dubina izostavljene su T-S. U detalnijem istraživanju zacijelo bi trebalo uključiti i sezonske analize. Posebna je pažnja posvećena vanjskim utjecajima (klimatskim elementima i hidrologiji). kao i unutarnjim (dinamici morske vode, izravnoj dinamičkoj vezi s Južnim Jadranom i neizravnoj sa Sredozemljem). Rezultati su potvrdili napore u pojašnjavanju postojećih uvjeta podrazumijevajući nastavak radnji na određivanju termohalinskih odnosa u ovom području. Kako su dobiveni na osnovi srednjih izračunatih vrijednosti, bilo bi povoljnije koristiti sezonska mjerenja kako bi se ispitale mjesečne godišnje vrijednosti kretanja temperature, slanoće i gustoće morske vode. Takav bi bristup zasigurno otvorio šire mogućnosti za druga znastvena polja i discipline.

SOMAIRE

Z. Bićanić, T. Baković: Une contribution à la connaissance des caractéristiques de l'eau entre le côté sud de Kornati et l'île de Žirje

Les analyses des conditions thermosalines de l'eau dans la zone observée: Kornati sud - l'île de Žirje, sont basées sur des données obtenues par les mesurages de longue durée. On a usé un grand nombre de données, et les séries de temps surpassent considérablement les standards usuels dans l'océanographie.

L'analyse thermosaline comprend aussi l'élaboration des données de température, de salinité et de densité de l'eau de mer. L'aproche méthodique offre plusieurs possibilités. On a choisi, pour cet article, les analyses des séries annulles des valeurs moyennes mensuelles à une profondeur particulaire et la distribution verticale des valeurs moyennes mensuelles. A cause de petites profondeurs T-S analyse a été omise. Il est évident que, dans une approche plus minutieuse, une analyse saisonniℵre devrait aussi ℘tre incluse. Une attention spéciale est donnée aux influences extérieures (éléments climatiques et hydrologie) et aux influences intérieures (dinamique de l'eau de mer et une dirrecte connexion dynamiquue avec le sud Adriatic et celle, indirrecte, avec la Méditerranée). Les résultats ont justifié les efforts faits pour les conditions existantes, et ils présument un travail ultérieur pour déterminer la conditionnement thermosalin dans cette espace. Etant donné que cela a été réalisé sur cette base, calculant des valeurs moyennes, on est d'avis qu'il serait avantageux d'appliquer des observations saisonnierℵs à fin d'analyser la distribution annuelle par mois des cours saisonniers des valeurs de température, de salinité et de densité de l'eau de mer. Une telle approche ouvrirait, sans doute, un vaste domaine pour d'autres champs et disciplines scientifiques.