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General conclusions

Ecological study of gas fields in the northern Adriatic

14. General conclusions

This paper deals with the results of ecological survey in the area of the gas fields IVANA and IKA in the northern Adriatic (Figs 1.1. and Fig. 1.2. in the Preface). Historical data as well as the data collected from the research platforms and research vessels in the period 1978-1986, have been analyzed.

The gas fields IVANA and IKA are situated in the region of the northern Adriatic shelf. The depths do not exceed 60 m, and the continental impact is considerable, as this part of the Adriatic has been deeply drawn into the continent. This is the reason why the most important oceanographic characteristic of this area is a distinct seasonal variability of parameters throughout the water column. It is contributed by an unequal seasonal inflow of the northern Italian rivers, especially the Po. Due to a large fresh water inflow (about 65 x $10^9 m^3$/year) the northern part of the Adriatic is a typical dilution basin. Local winds as well as other meteorological factors have a great influence on the physical characteristics. Under the influence of bora (NE wind), the frontal zone in the sea is occasionally developed. As compared to the whole Adriatic, the production is high, due to abundant fresh-water inflows.

Climatic elements have been analyzed according to the data collected on the research platforms in the fields of IVANA and IKA.A mean annual air temperature in IVANA is 15.8°C, while in IKA it is 17.7°C, which is much higher than on the Istrian coast (at Pula 13.9°C). The air temperature is higher on sea than on the coast throughout the year, while annual amplitudes are somewhat lower.

Air humidity is permanently higher than on the coast. In both fields, a mean monthly value is always above 70%. Cloudiness is permanently lower in the fields than on the coast, which is particularly strongly manifested in winter.

Predominant wind directions in both fields are NW, NE, SW and SE, or the directions along the Adriatic axis and vertical to it. In IVANA more pronounced is NW wind, while in IKA it is NE wind. Seasonal variations are prominent. Taken on an average, extreme speeds with squalls greater than 30 m s^{-1} occur 8 times in a year, mostly from NE and ENE (bora), ESE and SE (scirocco) and SW directions.

Surface waves were recorded in both fields, more often in IKA.With a strong wind, probability of occurrence of the waves higher than 3 m is about 13% for scirocco, while for bora it is about 3%. With scirocco, maximum heights are from 9.5 to 10.0 m, while with bora they are from 7.0 to 7.5 m. Periods of the scirocco generated waves are greater than the periods of the bora generated waves. Due to seasonal differences of the wind characteristics, distribution of the wave heights shows distinct seasonal variations. The greatest wave heights occur in winter. Absolute maximum in the measurement period of 7 years is 10.2 m with scirocco, while with bora it is 7.2 m.

Evolution of the wave spectra also differ with bora and scirocco, so that the decreasing period of bora is characterized by shifting of the wave spectra maximum toward higher frequencies, while with decreasing of scirocco, the wave spectra maximum remains on the same frequency. Differences between the bora generated waves and scirocco generated waves can be explained by different fetches, as the

fetch for scirocco is several times longer than the fetch for bora. As the two tested parameter approximations comparatively well approximate the real spectra, this enables computation of the wave spectra from the known wind speed and direction data. The prediction of extreme values for a 50-year significant return height is 10.4 m, while for the 100-year one it is 11.5 m.

A great number of current meter data from the research platforms in IVANA and IKA as well as from the launched drift-cards, provides a good illustration of the current field.

In general, circulation is slower in IVANA than in IKA. A mean scalar speed in the surface layer in IVANA is 12.5 cm s^{-1}, while in IKA it is 17.8 cm s^{-1}. The corresponding maximum speeds are 70.1 and 88.0 cm s^{-1}. In deeper layers, the speeds are lower and smaller are the differences between the fields. Nevertheless, higher speed classes are more frequent in IKA than in IVANA, in all layers.

Seasonal variations in the class distribution of speeds are most pronounced in the surface layer. In both fields the lowest speeds are more frequent in winter, and the highest ones in summer.

Residual circulation is slow and basically vertically homogeneous. Its speed is slightly lower in IVANA, where distinct seasonal variations in direction agree with variations in geostrophic circulation in the open middle Adriatic. A characteristic feature is an alternative share of N and S directions per seasons. In the field IKA the west direction is consistent throughout the year, in conformity with a constant west direction of geostrophic circulation in this zone. Residual directions are at the same time the most frequent ones.

In both fields and in all the layers, the highest kinetic energies of the mean circulation occur in the period August-November, with an increased share of the west component at the same time. In IKA this is at the some time the most frequent direction. In both fields with this direction occur the highest speeds.

However, in the current field oscillations are predominant. The highest values of their kinetic energies occur in the field IVANA in the warm period, with the maximum in June, in the surface layer, and a delay in deeper layers, while increased values occur in IKA simultaneously. This is connected with a greater share of the east current component. It is supposed that this is due to a frequent occurrence of inertial oscillations with a period of about 17 hours, which occur in the period of vertical stratification, after a sudden wind change. They have a distinct rotational movement, and this may cause higher frequency of those directions which differ from the residual ones. Higher scalar speeds in IVANA than in IKA during summer are also connected with a more frequent occurrence of inertial oscillations in the field IVANA.

Tidal currents occur in all depths, and are polarized toward the longitudinal axis of the Adriatic, having NW-SE directions. In the surface layer they are covered by the other components in a greater part, so that the NW-SE directions have lower speeds than the dominant directions, while in deeper layers they are dominant, having the highest speeds. Their semi-diurnal component is more pronounced from the diurnal. Their mean speeds are 5 cm s^{-1}.

In the period November-January, in the surface layer of the field IKA occur very high values of fluctuation kinetic energies, in relation with the occurrence of long-term oscillations in E-W direction, connected with passage of synoptic disturbances in autumn and winter.

Short-term oscillations with periods of several hours are less manifested.

As a rule, in both fields higher classes of speeds occur with W and NW directions, and lower classes with NE, E and SE directions.

Surface transport from the fields IVANA and IKA proceeds chiefly towards the western coast of Istria and the Italian coast from Venice to Ancona. A greater number of drift-cards from IVANA were found in northern coastal sectors, while from IKA in the southern ones,

which to some degree conforms with residual circulation of the surface layer in both fields. Otherwise wind is an essential factor for the surface transport, which is evident from the corresponding seasonal variations and comparison with the wind current model.

Wind generated circulation was examined, using a three-dimensional levels model. In the case of bora the topography and vorticity in the wind field have been considered while and in the case of scirocco wind field was considered as homogeneous.

In front of Venice, bora driven circulation forms an enclosed cyclonic gyre, while along the coast current from Trieste toward Venice is developed in the surface layer, being also visible in the vertically averaged circulation. More southward, an anticyclonic motion is developed, partly extending to all the layers. In the case of scirocco, characteristic of the surface layer is transport toward the northern part of the basin, which is particularly strongly developed along the Italian coast. In the bottom layer occur compensatory circulation in the middle of the basin.

Tidal amplitudes at the Istrian coast are the highest ones at the eastern coast of the Adriatic. The extreme range calculated for a return period of 100 years is 236 cm, being 14 cm higher than the one recorded during 28 years at Rovinj.

The main thermohaline characterictic of the Northern Adriatic is its marked continentality, and it also affects both of the gas fields. The sea temperature strongly changes throughout the year, passing from distinct vertical homogeneity in winter to very stratified layers in summer.

By the end of summer, thermocline in the field IVANA is descending almost to the bottom, while in IKA it remains shallower, which points to higher intensity of vertical mixing in IVANA. IKA shows a slightly lower annual temperature range. A mean sea temperature for all the levels according to BT measurements is 14.68°C in IVANA, while in IKA it was 14.84°C. The lowest temperatures in the upper layers were recorded in February, in both fields. Absolute extremes in IVANA were 6.3°C and 26.2°C, while in IKA they were 9.2°C and 27.0°C.

Salinity range in IVANA was 32.7 - 38.7‰ , while in IKA it was 37.1 - 38.8‰. Decrease in salinity was caused primarily by the river inflows, occurring from the surface to a depth of 15 metres. Annual course of salinity was slightly more variable in IVANA than in IKA, as IVANA is under a greater influence of the Po fresh-water inflows. In the surface layer, in both fields two maxima and two minima in a year occur.

Density follows the variations in temperature and salinity, but variations in density were sometimes caused only by temperature variations, due to the absence of halocline.

Transparency, turbidity and colour of the sea were under the influence of the river inflows from the west (field IVANA), as well as under the influence of the Istrian coast which extends along the frontal zone toward the open sea (field IKA). Differences in light extinction and transparency between the two gas fields were small. Seasonal variations in the light extinction and transparency were considerable, which is due to biological cycles of phytoplankton, seasonal influences of the river inflows as well as some dynamic factors.

For description of the content of oxygen and nutrient salts, the data from literature were used. The areas of the gas fields are rich with oxygen in all seasons, particularly in the colder part of a year. Maximum saturations occur between 10 and 30 m. In the field IVANA, the range of oxygen content and saturation values is somewhat greater than the one in the field IKA.

Ammonia is a dominant form of nitrogen salts in both fields. The ranges of nitrogen salts content are considerable, as they are influenced by different factors (fresh water and influence of Mediterranean waters). The content of silicate in the fields IVANA and IKA does not show such high maximum values as in the western parts of the northern Adriatic.

Deeper layers are richer with silicates.

The content of heavy metals and macroconstituents in the sea water was determined for the field IVANA, while the content of heavy metals in fish and mussels was determined in the samples collected between the cove Štinjan (Pula) and the field IVANA. For majority of metals, concentrations in the bottom samples are higher than the surface ones.

In spite of a small number of analyzed samples, it should be pointed out that the content of heavy metals in IVANA (cadmium, lead, copper and zinc) is somewhat increased, as compared with the other findings from the Adriatic. This is probably due to an intensive load from the industrially developed northern part of Italy. Concentrations of heavy metals in organisms are within the limits for unpolluted areas.

The analysis of macroconstituents did not show any concentration anomalies, which additionally confirms the fact that, according to the chemical parameters, the sea water in the study area has characteristics of unpolluted sea.

The contents of dissolved organic substances, polycyclic aromatic hydrocarbons (PAH), chlorinated hydrocarbons and (evaporable) phenols were analyzed in the field IVANA in March 1986.

The qualitative and quantitative determination of polyaromatic hydrocarbons were made in different media, because of pollution posibility which could be occured during the exploitation activity.

The obtained PAH concentrations in the sea water are characteristic for cleaner areas. Concentrations of phenol compounds are much lower than the concentrations in the area of the eastern coast. PAH contents in the sediment as well as in fish samples are at the level of slightly polluted localities. Mussels from the platform have increased amounts of PAH, due to discharge of the liquid waste from plants.

Contents of chlorinated insecticides are low, while the PCB contents show for an order of magnitude higher value than insecticides. Determined contents of chlorinated insecticides and PCBs in organisms are higher than those in sediments. Comparing the obtained concentrations of organic pollutants with those in the other localities in the Adriatic and Mediterranean shows that the field IVANA belongs to cleaner areas.

Pelagic communities are described partly according to literature partly on the basis of the recent investigations. Sampling of plankton organisms was carried ont in March 1986 (IVANA field). Study of ichtyopelagic communities was based on data of long-term investigations in the northern Adriatic (1974 to 1988). Statistical data of the pelagic fish yield during period 1972-1986 were also used.

Regarding to primary production, northern Adriatic is more productive areas than middle and southern Adriatic. In the northern part concentrations of chlorophyll a are for 1-2 orders of magnitude higher than those in the open waters of the middle and southern Adriatic. Considering to primary production, chlorophyll a biomass and phytoplankton density, northern Adriatic can be devided in two different parts: western, more productive side and eastern less productive side. Western side is strongly influenced by river Po inflow.

Area of IVANA and IKA fields are mostly influenced by open waters from the middle Adriatic which are less productive than northern Adriatic waters. Occasionally this area is influenced by high productive waters from the western Adriatic part. In this period it has been observed unusual spatial distribution of primary production and chlorophyll *a* biomass as well as great changes of dominant phytoplankton species.

In relation to the middle and southern Adriatic, northern Adriatic is caracterised by higher zooplankton biomass and less species diversity index of plankton copepod species. It has been presumed that sea currents in the eastern part of northern Adriatic bring numerous zooplankton larval stages from the middle and southern Adriatic.

Some of these organisms being returned back in autochtonous environment. Therefore, eastern part of the northern Adriatic is very important transit - area for many alochtonous plankton organisms.

Much higher density of heterotrophic bacteria (up to three times) was found in the area of the northern Adriatic, including the field of IVANA, than in the middle and southern Adriatic.

Pilchard is the major species in the catches of small pelagic fish in the waters of the western Istria and Kvarner. Sprat and anchovy are also well represented, together with the accompanying species like horse mackerel, mackerel and Spanish mackerel.

It has been observed that spatial-and-seasonal movements of sardine occur from the Gulf of Trieste toward the south and reversely, sprat from the Italian waters toward the west Istria and Kvarner and reversely, anchovy from the west Istria toward the Italian coast and vice versa.

Most frequent concentrations of small pelagic fish are in the west Istrian area. Variations in concentration of sardine coincide with its movement: in a warmer period of the year the population is spatially dispersed, while the autumn behaviour is characterized by the appearance of larger fish groups.

Absolute abundance of sardine stock during these researches, was estimated at 56.16 tons N m^{-2} in this area.

Extent of the sardine population in a greater area was in the process of growth. Sardine catch has seasonal character. Its variation is significantly connected with the degree of the fish aggregation.

The sardine population from the west Istrian waters is very homogeneous regarding its length (13.0 cm mode), isometric increase of length and weight, as well as Foulton's condition coefficient. The males are predominant. Conversly, the sardine from Kvarnerić and the channel Velebitski kanal is heterogeneous in regard to its length (modal length values from 15.0 and 17.0 cm). The length differences between the sardine of these two areas point to the existence of relationship between the sardine length and sea depth.

In total catches, sardine males were predominant.

With respect to the northern Adriatic anchovy, a considerable homogeneity has been noted regarding its length (modal values from 14.0 and 15.0 cm). Female predominate in total anchovy catches.

The sprat length ranges, their modal values as well as mean lengths values suggest the considerable homogeneity of sprat in the research period and area although there are two sprat subpopulations in the northern Adriatic area. Spawned females were predominant in total.

According to the gonad condition in the mackerel specimen, investigated during the spawning-time (winter, the beginning of spring), the mackerel specimen with total lengths up to 17.0 cm, had not yet reached their first sexual maturity.

Benthos communities in a greater area of the field IVANA are well developed, especially the zoobenthic communities on mobile deeper bottoms of the open part of researched area.

Communities of the benthic algae in a greater part of the littoral area are distinguished by a number of species and infraspecific relatives (246), being settled on solid (rocky and stony) seabeds. The remaining vast areas of deeper mobile (sediment) bottom in the open part of the area are almost without phytobenthic communities, as there has been determined only 15 species. In certain parts of the coast, from the point Proština (near Pula) to the point Kamenjak, especially in shallow-water phytobenthic communities, advanced stages of a degradation process, due to harmful effect of the increasing sea pollution, have been discovered.

Zoobenthic communities are well developed and include 296 macrozoobenthic species from three systematic groups. Diffusion of these communities is more uniform than the one of the phytobenthic communities.

A high biomass on deeper mobile bottoms of the open sea shows considerable fluctuations regarding mechanical structure of sediments. On chiefly muddy bottoms species from the Arthropod group are predominant, while on sandy bottoms prevail species from the Mollusca and Echinodermata groups.

Ichthiological (trawling) communities are very well developed on the mobile bottoms of a greater area of IVANA and IKA, which is confirmed by very high total amounts of zoobenthos of 47950 tons, from which an edible part (fish, crabs, mussels and cephalopods) accounts for 6680 tons, while the inedible one 41237 tons. From an economic point of view as regards fishery, a greater area of the gas fields is, for its abundance and variety of edible resources, an important part of the fishing in the open northern Adriatic.

Exposure of marine organisms to the impact of noxious substances has been tested by means of toxicological tests on mussels. No mutagens whatever were found in the mussels.

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Ekološka istraživanja plinskih polja u sjevernom Jadranu

Opći zaključci

Izneseni su rezultati ekoloških istraživanja u području plinskih polja IVANA i IKA u sjevernom Jadranu (Sl. 1.1. i 1.2. u uvodu). Korišteni su povijesni podaci kao i podaci prikupljeni s istraživačkih platformi i istraživačkih brodova u razdoblju 1978-1986.g.

Plinska polja IVANA i IKA su u regiji sjevernojadranskoga shelfa. Dubine ne prelaze 60 m, a znatan je kontinentalni utjecaj, jer je taj dio Jadrana duboko uvučen u kontinent. Zbog toga je osnovna oceanografska karakteristika područja izrazita sezonska promjenjivost parametara u cijelom stupcu vode. Tome pridonosi i nejednak sezonski upliv sjevernotalijanskih rijeka, a osobito rijeke Po. Zbog velikog dotoka slatke vode (cca $65x10^9$ m^3/godinu) sjeverni dio Jadrana je tipičan bazen dilucije.

Lokalni vjetrovi i drugi lokalni meteorološki faktori imaju vidan utjecaj na fizikalne karakteristike. Pod utjecajem bure, tu se povremeno u moru formira frontalna zona. Produkcija je u odnosu na cijeli Jadran visoka zbog obilnih slatkovodnih dotoka.

Klimatski elementi su obrađeni prema podacima prikupljanim na istraživačkim platformama na poljima IVANA i IKA.

Godišnja srednja temperatura zraka na IVANI je 15.8°C, a na IKI 15.7°C, što je znatno više nego na obali Istre (u Puli 13.9°C). Temperatura zraka je na moru viša tijekom godine nego na obali, a godišnje amplitude su nešto niže.

Vlažnost zraka je trajno viša nego na obali. Srednja mjesečna vrijednost je na oba polja uvijek iznad 70%. Naoblaka je na poljima trajno niža na obali, što je posebno naglašeno zimi.

Na oba polja dominiraju sjeverozapadni, sjeveroistočni, te jugozapadni i jugoistočni smjerovi vjetra, tj. smjerovi uzduž osi Jadrana i okomito na nju. Na IVANI je nešto izraženiji NW vjetar, a na IKI NE vjetar. Sezonske razlike su istaknute. Ekstremne brzine s udarima vjetra većim od 30 m s^{-1} se javljaju prosječno 8 puta godišnje, najčešće iz smjerova NE i ENE (bura), ESE i SE (jugo), te SW.

Površinski valovi su registrirani na oba polja, ali češće na IKI.

Uz jaki vjetar, vjerojatnost pojave viših valova od 3 m za jugo je oko 13%, a za buru oko 3%. Maksimalne visine uz jugo su u razredu 9.5 do 10.0 m, a uz buru 7.0 do 7.5 m. Periodi valova uzrokovani jugom su veći od perioda valova uzrokovani burom. Zbog sezonskih razlika karakteristika vjetra, raspodjela visina valova pokazuje izrazite sezonske razlike. Najveće visine valova se javljaju zimi. Apsolutni maksimum u razdoblju od 7 godina mjerenja uz jugo je 10.2 m, a uz buru 7.2 m. Uz buru i jugo je različita evolucija valnih spektara, pa je period smanjenja bure karakteriziran pomicanjem maksimuma spektra valova prema višim frekvencijama, a pri smanjenju jačine juga maksimum spektra valova ostaje na istoj frekvenciji. Razlike između valova uzrokovanih burom i jugom objašnjavaju se različitom dužinom privjetrišta ta dva vjetra, jer je povjetrište za jugo nekoliko puta veće nego za buru. Dvije parametarske aproksimacije relativno dobro aproksimiraju stvarne spektre, pa to omogućuje izračunavanje spektra valova iz poznatih podataka smjera i brzine vjetra. Prognoza ekstrenmih vrijednosti za 50-godišnju značajnu povratnu visinu daje 10.4 m, a za 100 - godišnju 11.5 m.

Veliki broj strujomjernih podataka s istraživačkih platformi na poljima IVANA i IKA, kao i bačenih drift-kartica , daje dobru sliku polja struja.

Strujanje je na IVANI općenito sporije nego na IKI. Srednja skalarna brzina u površinskom sloju na IVANI je 12.5 cm s^{-1}, a na IKI 17.8 cm s^{-1}. Odgovarajuće maksimalne brzine su 70.1 i 88.0 cm s^{-1}. U dubljim slojevima su brzine manje i manje su razlike između polja. Ipak, na IKI su u svim slojevima češće više klase brzina nego na IVANI.

Sezonske su razlike u raspodjeli brzina po klasama najizraženije u površinskom sloju. Na oba polja su najniže brzine češće zimi, a najviše ljeti.

Rezidualno strujanje je sporo i u osnovi jednoslojno. Na polju IVANA mu je brzina nešto manja, a izrazite sezonske promjene smjera se poklapaju s promjenama geostrofičkog strujanja u otvorenom srednjem Jadranu. Karakteristično je alternativno učešće N i S smjera po sezonama. Na polju IKA je zapadni smjer konzistentan tijekom cijele godine, također u skladu s trajno zapadnim smjerom geostrofičkog strujanja u toj zoni. Rezidualni smjerovi su ujedno i najčešći.

Najviše kinetičke energije srednjeg strujanja na oba polja i u svim slojevima se javljaju u periodu kolovoz-studeni s istovremenim povećanim udjelom zapadne komponente strujanja. Na IKI je to ujedno i rezidualni i najčešći smjer, a na oba polja se uz taj smjer javljaju najveće brzine.

U polju strujanja su, međutim, dominantne oscilacije. Najviše vrijednosti kinetičke energije oscilacije javljaju se na polju IVANA u toplom razdoblju s maksimumom u lipnju u površinskom sloju, sa zakašnjenjem u dubljim slojevima, a povišene vrijednosti se istovremeno javljaju i na IKI. Ovo je vezano uz veće učešće istočne komponente strujanja. Pretpostavlja se, da je to uzrokovano čestom pojavom inercijalnih oscijalcija s periodom od cca 17h, koje se javljaju u razdoblju vertikalne stratifikacije poslije nagle promjene vjetra. Imaju izrazito rotaciono gibanje, pa to može biti uzrok veće čestine smjerova različitih od rezidualnih. Više skalarne brzine na polju IVANA u odnosu na polje IKA u ljetnom razdoblju dovode se u vezu s češćom pojavom inercijalnih oscilacija na polju IVANA.

Plimne struje se javljaju u svim dubinama, a polarizirane su prema uzdužnoj osi Jadrana, tj. imaju smjerove NW-SE. U površinskom sloju ih većim dijelom prekrivaju ostale komponente, pa smjerovi NW-SE imaju manje brzine u odnosu na dominantne smjerove, ali u dubljim slojevima su dominantne i imaju najveće brzine. Poludnevna komponenta im je izraženija od cjelodnevne. Srednje brzine su im 5 cm s^{-1}.

Na polju Ika se u površinskom sloju u razdoblju studeni-siječanj javljaju vrlo visoke vrijednosti kinetičke energije fluktuacija u vezi s pojavom dugoperiodičkih oscilacija, koje se odvijaju u smjeru E-W, a vezane su za prolaze sinoptičkih poremećaja u jeseni i zimi. Udio kratkoperiodičkih oscilacija s periodima od nekoliko sati je manje izražen.

Na oba polja više klase brzina javljaju se u pravilu uz smjerove W i NW, a niže klase brzina uz smjerove N, NE, E i SE.

Površinski transport s polja IVANA i IKA se odvija pretežno prema zapadnoj obali Istre i talijanskoj obali od Venecije do Ancone. Veći broj drift-kartica s IVANE je nađen u sjevernijim, a s IKE u južnijim zonama, što je donekle u skladu s rezidualnim strujanjem površinskog sloja na oba polja. Vjetar je inače odlučan faktor za površinski transport, što je vidljivo iz odgovarajućih sezonskih razlika, te usporedbom s modelom struja vjetra.

Strujanje uzrokovano vjetrom ispitano je pomoću trodimenzionalnog modela. Ispitano je djelovanje bure uzimajući u obzir topografiju i vrtložnost u polju vjetra, te djelovanje juga, koje promatramo kao homogeni vjetar. Uz buru je razvijena zatvorena ciklonalna ćelija ispred Venecije, a duž obale je razvijeno strujanje od Trsta prema Veneciji i to u površinskom sloju, ali uočljivo i na srednjem strujanju za cijeli stupac. Južnije se formira anticiklonalna cirkulacija, koja također dije-

lom zahvaća sve slojeve. Uz jugo je u površinskom sloju karakterističan transport prema sjevernom dijelu bazena, osobito izražen uz talijansku obalu. U pridnenom sloju javlja se kompezacijsko strujanje po sredini bazena.

Amplitude plime i oseke na istarskoj obali su najviše na istočnoj obali Jadrana. Izračunat ekstremni raspon za povratni period od 100 godina je 236 cm i za 14 cm je viši od registriranog tijekom 28 godina u Rovinju.

Osnovna termohalina karakteristika sjevernog Jadrana je njegova izražena kontinentalnost, pa se to odnosi i na oba plinska polja. Temperatura mora se jako mijenja tijekom godine i prolazi kroz ciklus promjena od izrazite vertikalne homogenosti zimi do vrlo stabilno stratificiranih slojeva ljeti. Krajem ljeta se termoklima na polju IVANA spušta skoro do dna, a na IKI ostaje plića, što ukazuje na veći intenzitet vertikalnog miješanja na IVANI. IKA ima i nešto manji godišnji raspon temperature. Srednja temperatura za sve nivoe prema BT mjerenjima na IVANI je 14.68°C, a na IKI je 14.84°C. Najniže temperature u gornjim slojevima su na oba polja registrirana u veljači. Apsolutni ekstremi na IVANI su 6.3°C i 26.2°C, a na IKI 9.2°C i 27.0°C.

Raspon slanosti na polju IVANA je 32.7 - 38.7‰, a na polju IKA 37.1 - 38.8 ‰. Zaslađenje je uzrokovano prvenstveno riječnim dotocima, a javlja se od površine do 15 m dubine. Godišnji je hod slanosti na IVANI nešto promjenjiviji nego na IKI, jer je IVANA pod većim utjecajem dotoka slatkih voda Po-a. U površinskom se sloju tijekom godine javljaju na oba polja dva maksimuma i dva minimuma.

Gustoća slijedi promjene temperature i slanosti, ali su promjene gustoće zbog odsustva halokline, ponekad uzrokovane samo temperaturnim razlikama.

Prozirnost, turbiditet i boja mora su pod utjecajem riječnih dotoka sa zapada (polje IVANA), ali i pod utjecajem obale Istre čiji se utjecaj širi duž frontalne zone prema otvorenom moru (polje IKA). Malene su razlike ekstincije svjetlosti i prozirnosti između dva plinska polja. Sezonske promjene ekstincije i prozirnosti su znatne, što je uvjetovano biološkim ciklusima fitoplanktona, sezonskim utjecajem riječnih dotoka, ali i dinamičkim čimbenicima.

Za prikaz sadržaja kisika i hranjivih soli korišteni su literaturni podaci. Područje plinskih polja je u svim sezonama bogato kisikom, a osobito u hladnijem dijelu godine. Maksimalna zasićenja se javljaju izmedu 10 i 30 m. Na polju IVANA je nešto veći raspon vrijednosti sadržaja kisika i zasićenja, nego na polju IKA.

Amonijak je dominantna forma dušikovih soli na oba polja. Rasponi sadržaja dušikovih soli su znatni zbog raznih faktora koji utječu na njihov sadržaj. Sadržaj silikata na poljima IVANA i IKA ne pokazuje izrazito visoke maksimalne vrijednosti kao u zapadnim dijelovima sjevernog Jadrana. Dublji slojevi su bogatiji silikatima.

Sadržaj teških metala i makrokonstituenata u morskoj vodi određen je za polje IVANA, a sadržaj teških metala u ribama i školjkama na uzrocima s poteza: uvala Štinjan (Pula)- polje IVANA.

Za većinu metala koncentracije su u pridnenim uzorcima više od površinskih. Unatoč malog broja analiziranih uzoraka, može se zaključiti da je u usporedbi s drugim nalazima u Jadranu, na IVANI sadržaj teških metala (kadmij, olovo, bakar, cink) nešto povećan, vjerojatno zbog intezivnijeg opterećenja iz industrijski razvijenog sjevernog dijela Italije. Koncentracije teških metala u organizmima su u granicama za nezagađena područja.

Analiza makrokonstituenata nije pokazala nikakve koncentracijske anomalije što je dodatna potvrda da u istraživanom akvatoriju, prema kemijskim parametrima, morska voda posjeduje karakteristike čistog mora.

Sadržaj otopljene organske tvari, policikličkih aromatskih ugljikovodika (PAH), kloriranih ugljikovodika i hlapivih fenola analiziran je na polju IVANA u ožujku 1986. Težište istraživanja je na kvalitativnom i kvantitativnom određivanju poliaromatskih ugljiko-

vodika u različitim medijima koji bi mogli biti ugroženi u budućoj eksploataciji.

Koncentracije PAH u morskoj vodi su karakteristične za čišća područja.

Koncentracije fenolnih spojeva su dosta niže od koncentracija u obalnom pojasu istočne obale. Udjeli PAH u sedimentu su na nivou neznatno onečišćenih lokaliteta, slično kao i u uzorcima riba. Školjke s platforme imaju povećane iznose PAH zbog ispuštanja otpadnih voda iz postrojenja.

Koncentracije kloriranih insekticida su niske, dok su PCBs u iznosima višim za red veličine, ali i jedni i drugi imaju evidentan trend smanjenja koncentracija. Sadržaj kloriranih insekticida i PCBs u organizmima ukazuje na nešto više iznose nego u sedimentu.

Usporedba nađenih koncentracija organskih zagađivala s drugim lokalitetima na Jadranu i Mediteranu pokazuje da polje IVANA spada među čišća područja.

Pelagijske zajednice su dijelom prikazane prema literaturi. Uzorkovanje planktonskih organizama je provedeno jedino na polju IVANA u ožujku 1986. Korišteni su također statistički podaci o ribolovu u razdoblju 1972-1986. godine.

Sjeverni Jadran je s obzirom na primarnu proizvodnju produktivno područje. Koncentracije klorofila *a* u tom bazenu su za 1-2 reda veličine više od onih u otvorenim vodama srednjeg i južnog Jadrana. Na bazi primarne produkcije, kao i biomase te gustoće fitoplanktona, moguće je diferencirati bogatiju, zapadnu stranu, koja je pod utjecajem riječnog dotoka, i siromašniju, istarsku stranu.

Polja IVANA i IKA se većim dijelom nalaze pod utjecajem voda s juga, koje su siromašnije. Samo se povremeno u tom području može zapaziti utjecaj bogatije vode sa zapadne obale na što ukazuje prostorna distribucija primarne proizvodnje i klorofila *a*, te horizontalna raspodjela dominantnih fitoplanktonskih rodova.

Sjeverni Jadran je također bogat zooplanktonskom biomasom, ali ima manju različitost vrsta od otvorenih voda ostalog Jadrana.

Pretpostavlja se da iz srednjeg i južnog Jadrana u istočni dio sjevernog Jadrana dolazi velik broj različitih larvalnih stadija zooplanktonskih organizama od kojih se neki, kruženjem struja, ponovno vraćaju u svoj izvorni areal. Zato je važno tranzitno područje za meroplanktonske kao i za holoplanktonske organizme.

Na području sjevernog Jadrana, uključujući polje IVANA, utvrđena je znatno veća gustoća heterotrofnih bakterija (i do tri puta) nego u srednjem i južnom Jadranu.

U ulovima male pelagičke ribe u zapadno istarskim kao i u kvarnerskim vodama srdela je glavna vrsta. Papalina i brgljun također su dobro zastupljeni, uz prateće vrste kao što su šnjur, skuša i plavica.

Uočeno je prostorno-vremensko kretanje srdele od Tršćanskog zaljeva prema jugu i obratno, papaline od talijanskih voda prema zapadnoistarskom području i Kvarneru i obratno, brgljuna od zapadnoistarskog područja prema talijanskoj obali i obratno.

Najčešće koncentracije male pelagične ribe nalaze se u zapadnoistarskom području. Promjene u koncentraciji srdele podudaraju se s njenim kretanjem: u toplijem razdoblju populacija je prostorno dispergirana, dok je za jesensko ponašanje karakteristično pojavljivanje većih grupacija riba.

Apsolutna je abundancija stoka srdele, za vrijeme ovih istraživanja u tom području procijenjena na 56.16 tona N m^{-2}.

Veličina populacije srdele u širem području nalazila se u procesu rasta.

Ulov srdele ima sezonski karakter. Varijacija njezina ulova je signifikantno povezana sa stupnjem agregacije populacije ribe.

Srdela zapadnoistarskih voda vrlo je homogena u odnosu na dužinu, (modus od 13.0), izometrijski porast dužine i težine, FOULTONOV koeficijent kondicije te prevladavanja mužjaka. Za razliku, srdela iz Kvarnerića i Velebitskog kanala je heterogena u odnosu na dužinu (modalne vrijednosti od 15.0 do 17.0 cm). Razlike u veličini između srdele ovih dvaju područja ukazuju na postojeći odnos između srdele i dubine.

U svim su lovinama prevladavali mužjaci srdele. Kod primjeraka brgljuna sjevernog Jadrana uočena je znatna homogenost u odnosu na dužinu (modalne vrijednosti od 14.0 i 15.0 cm) te veća zastupljenost ženki u svim lovinama.

Rasponi dužine papaline, njihove modalne vrijednosti kao i srednje vrijednosti dužina ukazuju na znatnu homogenost papaline u vremenu i području istraživanja. U svim lovinama prevladavale su izmriješćene ženke. U području sjevernog Jadrana papalina ima dvije subpopulacije.

Sudeći prema stanju gonada primjeraka skuše, izučavanih u vrijeme kada se inače skuša mrijesti (zima, početak proljeća), primjerci skuše totalnih dužina do 17.0 cm uključivo nisu još bili dosegli svoju prvu spolnu zrelost.

Bentoska naselja na širem području polja IVANA su dobro razvijena, posebno zoobentoska naselja na pomičnim dubljim dnima otvorenog dijela istraženog područja.

Naselja bentoskih alga se na većem dijelu priobalnog područja odlikuju brojnim vrstama i infraspecifičnih svojti (246) koje naseljavaju čvrsta (stjenovita i kamenita) dna. Ostale znatne površine dubljeg pomičnog (sedimentnog) dna na otvorenom dijelu područja gotovo da su bez fitobentoskih naselja, jer je tu određeno samo 15 vrsta. Na pojedinim dijelovima obale od rta Proštine (kod Pule) do rta Kamenjak su, posebno u plitkovoednim fitobentoskim naseljima, zapažene uznapredovale faze degradacijskog procesa uslijed štetnog učinka rastućeg onečišćavanja mora.

Zoobentoska naselja su dobro razvijena i obuhvaćaju 296 makroobentoskih vrsta iz triju sistematskih skupina. Rasprostranjenost tih naselja je jednoličnija od fitobentoskih naselja. Visoka biomasa na dubljim pomičnim dnima otvorenog mora pokazuje znatna kolebanja u odnosu na mehaničku strukturu sedimenta. Na pretežno muljevitim dnima prevladavaju vrste iz skupine Arthropoda, a na pješćanim dnima vrste iz skupiona Mollusca i Echinodermata.

Ihtiološka (koćarska) naselja su vrlo dobro razvijena na pomičnim dnima šireg područja polja IVANA i IKA što dobro potvrđuju dosta visoki ukupni iznosi količine zoobentosa od 47950 tona, od čega na jestivi dio (ribe, rakovi, školjke i glavonošci) otpada 6680 tona i nejestivi 41237 tona. U ribarstveno ekonomskom pogledu šire područje naftnih polja, radi obilja i raznolikosti jestivih resursa, predstavlja značajan dio ribolovnog otvorenog sjevernog Jadrana.

Izloženost je morskih organizama utjecaju štetnih tvari ispitana pomoću toksikoloških testova na dagnji. U školjkama nisu nađene mutagene tvari.

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