Acta Adriat.,32(2):545-554(1991) ISSN:0001-5113
AADRAH

UDC:061.6(047.1)"1980-1990"
Review

RESULTS OF THE RESEARCH ACTIVITIES OF THE INSTITUTE OF OCEANOGRAPHY AND FISHERIES, SPLIT, FOR THE LAST TEN YEARS

IZVJEŠTAJ O REZULTATIMA RADA INSTITUTA ZA OCEANOGRAFIJU I RIBARSTVO, SPLIT, TIJEKOM PROTEKLIH DESET GODINA

T. Pucher-Petković

Institute of Oceanography and Fisheries, Split, Croatia

This Report, written on the occasion of the 60th anniversary of the Institute of Oceanography and Fisheries in Split, presents the results of the research carried out over the past decade. Some important moments in the history of this Institute are also mentioned.

Although the beginning of the research of the Adriatic Sea may be traced back to the preceding century and some extensive expeditions were accomplished later, it became very soon obvious that the foundation of a national institution which would carry out permanenet and systematic research of the sea was indispensable. This, however, was realized not earlier than in 1930, supported and initiated by national academies of sciences and authorities interested in this field of activity. So the Institute was founded as the Biological-Oceanographic institute to become the Institute of Oceanography and Fisheries after the second world war.

In the pre-war period the Institute's activities mainly covered the studies of productivity of the coastal sea surrounding Split. Fishery-biology studies of pelagic and benthich fish also began at that time. These studies provided a basic information on the principal links of marine food chains.

The approach to the research had an ecological character, considering the Adriatic as a complex ecosystem in which biotic and abiotic elements make an entity.

In the post-war period the field of research was broadened, new disciplines such as sea water dynamics, geology, ichthyoplankton, bacterioplankton, phytobenthos and biochemistry being included. Fishery investigations included also fishing techniques, statistics and fishery economy. The scope of these studies was to establish the productive potential of the Adriatic Sea at different trophic levels.

For the past decade scientific activities of the Institute have been intensified, particularly as far as physical oceanography is concerned. At the same time different aspects of Man's impact on the sea and its life have been included in the research.

The Institute is now organized in five laboratories: Laboratory for marine physics, Laboratory for marine chemistry, Laboratory for marine biology, Laboratory for ichthyology and fisheries and Mariculture laboratory.

For the most part the research is organized as a team work, being the best approach to ecological problems.

Natural features of the Adriatic are studied, particularly dynamical and chemical processes, productivity of the pelagic zone, as well as plant and animal components of benthos.

The research also includes biological-ecological aspects of pelagic and demersal fish populations, experimental fish rearing and moreover testing and improvement of some fishing gear.

Extensive research of Man's impact on the marine environment is also performed, including sea water, sediment and plant and animal organisms.

The Biological Research Station in Dubrovnik has been a special scientific unit of the Institute since 1977. The research activities of the laboratory in Dubrovnik cover primarily planktonic biocoenoses as affected by hydrographic and chemical parameters. This laboratory is also engaged in artificial rearing of different life stages of fish and shellfish. In addition, a part of the activities includes the studies of flora and vegetation of the mainland.

In this Report, however, only the accomplishments of the Institute in Split are presented.

The research of the sea water dynamics has been evolving in two directions, the studies of small coastal basins and the circulation in the open sea and water exchange between the Adriatic and Ionian Sea.

The kinematics and dynamics of small coastal basins is studied experimentally and by means of numerical hydrodynamic models. So the wind effects on current field and water exchange are well known in the Kaštela Bay, Vir Sea, Rijeka Bay and the northern Adriatic basin. In the Kaštela Bay this research is a part of a complex study of unusual phytoplankton blooms. The characteristics of water exchange of the Bay with the adjacent basins, as the function of wind, were determined. *In situ* data were compared to the results obtained by numerical hydrodynamical models. Homogeneous and stratification model has been applied for the northern Adriatic and wind response studied under different conditions of vertical stratification of water mass. Satelite images show that bora frequency is related to the position of the thermal front in the northern

Adriatic.

Long-term studies of the open sea have been continued. Some of the characteristics of seasonal and several day variations of residual flow as well as those of water exchange through the Strait of Otranto may be obtained by the analysis of sea level variations in the Adriatic, Ionian and Aegean Sea and their interrelations at time scales of from several days to two months. It has been established that the sea level oscillations are related throughout this Mediterranean part and that the variability is caused by planetary waves and synoptical atmospheric disturbances. Climatic changes in the Adriatic are related to climatic changes in the entire Eastern Mediterranean. However, substantial differences between climatic time scales have been observed within the same area. A comparison with the Black Sea has also been made. It is assumed that the water exchange between the Adriatic and the Ionian Sea is also variable at a time scale of several days apart from the seasonal and long-term scale.

The hydrographic data, as well as some biological and chemical parameters, prove cyclonic gyre in the southern Adriatic to be persistent. Recent investigations of some German oceanographers, who used radioactive elements, agree with the mean transport of water through the Otranto Strait of about 0.3 Sverdrups (0.3×10^6 m^{-3} s^{-1}) calculated at our Institute.

Long-term regular observations of basic hydrographic and chemical parameters at permanent stations of the Institute, and if necessary at some other localities, have been continued. To improve accessibility to the collected data computerised information system is being developed. These data are now being brought together into a database. Up to now the segments for physical oceanography and chemistry have been completed, and the segment for fisheries is being prepared.

Plankton productivity has been continuously surveyed in the middle Adriatic for over 30 years.

The phytoplankton productivity has been increasing in the open waters of the middle Adriatic ever since 1980 being by 34% higher during this decade than during the preceding twenty years. This increase in primary production affects factors closely related with photosynthetic processes. So oxygen saturation has been increasing in the upper sea water layers due to the intensified organic matter synthesis, and decreasing in the bottom layers due to its intensified decomposition. In addition, the increase of the densities of heterotrophic bacteria, the organic matter decomposers, coincides with the productivity increase. During the past decade transparency has been decreased throught the middle and southern Adriatic to an extent roughly corresponding to the double number of particles in the sea in relation to the preceding period. The ratio of mineral nitrogen components to phosphates has been reduced. These results point to the impact of eutrophication of land origin which is believed to be a continuation of the processes present in the coastal middle Adriatic ever since 1968. It has also been found that the relationship between earlier distinguished productivity zones had changed, that is that richer coastal waters had expanded towards the open sea and from the northern to the middle Adriatic. This, normally, has affected an incresase in small pelagic fish catch. Already in 1980 the first signs of "neritization" of open waters were observed,

manifested as density increase and spreading of some neritic planktonic forms in the open sea.

As a part of the same project the proportion of dominant zooplankton groups has been determined as well as their seasonal and twenty-year variations in the open sea as affected by abiotic and biotic factors. In the spring, the period of intensified water mass dynamics, plankton composition on the eastern Adriatic side is most similar to that on the western side, copepods making up to 99% of the total zooplankton density. The autocorrelation method shows fluctuation periods for copepods of two and three years, as earlier established for sardine catch in the Adriatic Sea.

The plankton research includes the composition and fluctuation of developmental fish stages - eggs, larvae and postlarvae. Development of anchovy, their larvae and postlarvae has been experimentally studied at different temperatures, which made possible later studies of mortality and survival of these fish under natural conditions. Age of postlarvae has been determined by newly adopted method of daily growth of otolith rings. The impact of "upwelling" and generally the impact of frontal zones on spawning centres formation in the Adriatic have been investigated.

As a part of plankton research seasonal and year-to-year studies of the role of heterotrophic bacteria in decomposition of organic matter and particularly the role of their different physiological groups have also been carried out. In addition, bacterioplankton biomass, rate of biomass changes and its diurnal increment have also been investigated. The first data on the importance of bacterioplankton in the organic matter circulation in the Adriatic have also been reported. These studies show that the production of bacterioplankton may constitute up to 28% of the total phytoplankton production in the coastal middle Adriatic and up to 40% in its open part.

Unusual plankton blooms have been examined of which at last those of plant origin are presumably related to intensified eutrophication. They have recently become particularly frequent in the Adriatic. So the summer diatom blooms, appearing during one of their developmental phases as mucilaginous mass floating on the sea surface, have been investigated.

Studies of red tides caused by monospecific blooms have also yielded new information. The knowledge of the causes of initiation, spreading and termination of blooms is indispensable as well as the responses of other organisms to drammatically changed conditions in the sea. Suspect toxic phytoplankton species, earlier reported for the Adriatic, have also been analysed. It has been found that six such species are present in the Adriatic.

Exceptional blooms of zooplankton have also been recorded. Some years showed just the "explosions" of planktonic crustaceans, *Noctiluca*, appendicularians or jellyfish. Our scientists have formulated several hypotheses of the causes of *Pelagia noctiluca* expansions in the Adriatic, Mediterranean and a part of the Atlantic. However, the occurrence of *Pelagia* seems to be due to a combination of many factors indicative of serious disturbances in ecosystems.

Feeding relations have been studied in the pelagic zone. Size structure of primary producer - phytoplankton, which affects the efficieny of the transport of energy and

organic matter through marine food chains, has also been investigated. Gut contents of primary consumers (herbivore copepods) reflect, to a considerable extent, phytoplankton composition in the sea. This points to the fact that they do not select food. The number of cladocerans is ultimately dependent on bacteria on which they feed. It has also been examined how the occurrence of jellyfish is related to fish catch.

Research of the benthos includes phyto- and zoobenthos. As a part of the phytobenthic research, the studies of benthic algal flora have been performed. In the recent years these researches have been extended in the middle Adriatic and to the southern Adriatic which in this respect had been completely unknown. So a total of 412 algal taxa have been recorded from the southern Adriatic. The revised inventory from the middle Adriatic includes 531 taxa. This has provided the basis for a rather complete inventory of benthic flora of the entire Adriatic.

Benthic vegetation studies cover the settlements of dominant algae and phanerogams. These settlements are characterized by very rich and diversely associated flora of benthic algae. So a total of 150 taxa have been determined from the *Cystoseira barbata* settlement, and 181 from that of *Posidonia oceanica*. Phytocoenological analyses have made possible the identification of some plant associations in the Adriatic benthic vegetation.

Studies of benthic biocoenoses include floral and fanual composition, dynamics and vertical and horizontal distribution of benthic communities. Special attention has been given to photophylous algae, coralline biocoenoses and biocoenoses of *Posidonia oceanica* meadows, the former two inhabiting rocky and secondary hard bottoms and the latter mobile bottoms.

Associated observations of the biology, distribution and biomass of the shellfish *Pecten jacobeus, Chlamys opercularis* and *Lithophaga lithophaga* were performed. The depth distribution of the first two species in the northern Adriatic was established and their biomass estimated at 22.000 and 89 tons respectively per an area of about 10.000 square km. The state of date shell (*Lithophaga lithophaga*) has been estimated for the purpose of their protection and the protection of the entire littoral part important as a habitat of a number of plant and animal species. The studies of this species include its reproductive cycle, biometric relations and growth rate.

A monograph presenting information on about a hundred species of gastropods (Prosobranchia group) has contributed to the inventory of the Adriatic organisms.

Over the last decade the Institute has supported a series of biological and ecological studies of pelagic fish, sardine, anchovy, mackerel, sprat, horse mackerel and tuna; different biological aspects of their life cycle have been investigated, in particular growth and reproduction, with the view to determine their reproductive potential and in this connexion, stock variations.

Anchovy population is homogeneous in the middle Adriatic. They first mature at the end of the first year of age, at 8.6 cm male length and 9.7 cm female length. Catches from the middle Adriatic show anchovy up to the four years of age.

Absolute sardine fecundity varies between 11 and 82 thousands of ripe oocytes. The catches are dominated by sardine exceeding three and four years of age, whereas the

oldest sardine found was more than eight.

Moreover, small pelagic fish has been studied by acoustic method - echosounder. Fish abundance, recorded by echotraces, has been analyzed in relation to the environmental factors. The same method has been applied for spatial distribution studies of these fish, as well, that is their migrations and seasonal distribution. An analysis of fish landings and data obtained by echosounder, has shown that sardine constitute up to 90% of the total pelagic fish in the Adriatic.

Observations have been carried out of the effects of increased intensity of commercial fishing on pelagic fish populations. So, the maximum sustainable yield has been determined for sardine, tuna and horse mackerel by analytical and global models. Long-term data series on catch and fishing effort provide all the information on spatial and temporal distribution and abundance of commercially important populations as well as on some population parameters such as natural and fishing mortality and exploitation level.

The efficiency of pelagic trawlers and purse seiners in small pelagic fish fishing has been analyzed, and a mathematical model for determination of optimum engine power of pelagic trawls has been developed.

Small pelagic fish stock has been assessed on several occasions. The cooperation with Italian scientists results in the sardine and anchovy stock assessment, on the basis of eggs and relative fecundity, at 300 and 800 thousand tons respectively.

Middle Adriatic sardine stock, assessed on the basis of growth parameters and mortality and survival coefficients, amounts to 91 thousand tons at the exploitation rate of 0.3 tons.

The assessment of the state and size of stocks on the basis of catch statistics and fishing effort has been made for the most exploited pelagic fish. It has been attempted to forecast pelagic fish catch using meteorological factors, pelagic fish catch and abundance estimated by echotraces.

Biological and ecological research of demersal fish includes origin, structure, zoogeographic distribution and peculiarities of the Adriatic ichthyofauna as a whole, as well as the presence of some fish species in the Adriatic and biology and ecology of rare and commercially important fish species. Data on parasite helminthofauna have been collected and reported for the mid Dalmatian area.

Data from the Jabuka Pit, a unique morphological, ecological, floral, faunal and productivity area in the Adriatic, have been interpreted and published as a monograph "Fauna and Flora of the Adriatic, Jabuka Pit".

Comparative investigations of the Adriatic trawling grounds started at the beginning of 1981 in collaboration with the institute in Fano (Italy). They include most of the Adriatic continental shelf. The results have lead to the conclusions on the selectivity effects of bottom trawls, which may be of significant assisstance in the protection of fish and crustacean settlements. It has also been established that B e v e r t o n & H o l t model is not an appropriate protective measure for our conditions with high diversity of fish populations. This cooperation has also resulted in establishing the extent of distribution of individual benthic populations, the assessment of their quantities as well

as determination of dominant groups in relation to the bottom type and depth. These data have been used as a basis for the construction of biocoenological maps. They also made possible the establishment of the relationship between edible and nonedible parts of trawl catches.

The construction of fishing gear for demersal fishing has been improved as well as the way of its rigging.

The state and size of fish stocks have been assessed by an analysis of commercial trawl catch statistics. The hypothesis of unique stocks of commercially important fish species in the Adriatic basin has also been confirmed. This arises the question of the necessity of the Adriatic "middle line" for fishery purposes. The agreement between Italian and Croatian fishery experts as well as the coordination of legislative protective measures has been reaffirmed as indispensable.

The effects of coastal fishing with respect to the resources, exploitation level and protection have also been studied. Trammels, beach trawls, beach seines and some other small-scale fishing nets have been tested. The methods of fishing by nets with ropes for fish scaring have been separately tested. Some of the results are of practical application in fishery legislation for protection of both individual species and resources as a whole.

The Institute's activities in mariculture promotion should also be emphasized. For these purposes the ecology of juveniles of commercially important species has been intensively investigated as well as artificial spawning and rearing of early stages of sea bass and gilthead sea bream. The phenomenon of mass mortality of postlarvae, immediately prior to metamorphosis, presumably due to the hypertrophy of swimbladder, has been solved in practice. So, for the time being, about 40% of artificially reared sea bass could be cultured to the juvenile stage which is a rather significiant achievement in the rearing process.

Phyto- and zooplankton species are cultured for food of early developmental fish stages. Nutritive value of zooplankton has been examined by feeding them different food types.

Developmental stages of autochthonous brine shrimp (partenogenetic *Artemia* from Sečovlje) have been found to be too large to serve as food to newly hatched fish. Therefore another *Artemia* species has been inoculated at Ston saltern. This species has got well adapted to the ecological conditions of this saltern biotope. The next step of these investigations is to examine whether adaptation by dredging of saltern ponds for its large-scale rearing is commercially justifiable.

Biochemical composition (proteins, lipids and carbohydrates) of mullet and date shell have also been studied. It is interesting that the ratio flesh weight to shell weight is constant, irrespective of date shell size, whereas the flesh part with intervalvular water makes up one third of its total weight.

Almost all the important results have been tested by a long-term pilot production with a scope to provide conditions for commercial production of sea bass at adequate localities along our coast. Juveniles were stocked in cages of the MIRNA - Rovinj firm in the channel Limski kanal. This cooperation has also been extended to private enterprises to explore the possibility of cage culture in the small Bay of Pirovac.

Juveniles have also been reared for fishing ponds of the UNION DALMACIJA firm - Split in the Marina Bay, where the pilot production of marine fish have already started with anticipated production of 10 fish tons and 50 shellfish tons.

Man's impact on the sea and its life makes a significiant part of Institute's activities. These investigations are carried out through over a number of financed projects commissioned by different national bodies, international organizations or industry.

During the past decade, as well as earlier, the Institute has realized a series of ecological investigations at different localities all along our coast. The scope of these reports is to provide information on the capacities of the coastal sea and to propose best solutions for promotion of water quality for different purposes such as tourism, fisheries, and mariculture (fish and shellfish).

The results of most of these investigations especially of long-term ones, are of notable scientific importance. So, for example, in the Kaštela Bay, data series of continuous monthly observations of physico-chemical and biological parameters are available for the period ever since the fifties of this century. Therefore, the man made effects have been first and most easily observed in this area, particularly since this bay is one of the most threatened areas of our coastal belt. The results of the investigations of coastal belt problems embrace the eutrophication, sanitary microbiology, pollution by organic and anorganic pollutants and their impact on the sea and its life and particularly toxicological studies.

Long-term research of hydrographic and chemical parameters, indicating the level of production of an aquatic area, have shown that the quantity of nutrients increased during the first eutrophication phase, whereas now, during the more advanced stage, the ratio of mineral components of nitrate to those of ortophosphate has decreased. This is indicative of the effects of sewage effluents on this bay. Oxygen saturation has decreased in the bottom layer and sea water transparency has been reduced.

Planktonic community first responds to the regime changes. This was observed in the Kaštela Bay as early as in 1968. Apart from the gradual increase of productivity, density and biomass of phytoplankton, seasonal cycle has been altered by the occurrence of the third, summer maximum, the phenomenon later recorded for zooplankton, as well. Changes have been observed also in the community structure with particularly altered ratio between species, which culminate with the occurrence of "red water" when a single species becomes dominant, practically forming monoculture. Decrease in diversity index of copepods has been recorded. Some species have been found to be eutrophication indicators. Increase in the quantities of heterotrophic bacteria coincides with this phenomenon, and the relationship between their different physiological groups may point to the effluent type.

Benthic communities respond slower to eutrophication effects, response being manifested as an increase in biomass of some species. Some of the species retire and are replaced by more euryvalent species. Of algae, nitrophilous species develop particularly well. Some of them may be taken as indicators of eutophicated environment. Of animal species this is particularly true for mussel.

It has been established that the coastal area of Split along with the Kaštela Bay, is

strongly affected by faecal pollution. The concentrations of faecal pollution indicators at a number of recreational zones are highly in excess of legal maximum permissible limits. Level of faecal coliforms in shellfish also points to very strong pollution, the values highly exceeding maximum permissible limits for consumption.

Of organic pollutants polycyclic aromatic hydrocarbons (mineral oils) have also been studied in the sea water, sediment, shellfish and fish from both the coastal area and open sea. The Adriatic waters are not, in general, contaminated with these pollutants. However, the values of aromatic hydrocarbons are very high in the Split harbour sediment. The lowest concentrations of this pollutant have been recorded from the tissue of date shell from the area of Dugi otok. Phenols and detergents have been studied only in the coastal waters.

A potential loss of fish biomass at hypothetical spill of mineral oils has been assessed for the Bay of Rijeka, at 600 kg per 100 tons of spilled oil.

The acute toxicity of different concentrations of an oil dispergator (BP 1100 WD) to developmental stages of sea bass has been tested. The survival of exposed eggs proves to be relatively high, whereas the time to hatching is either shortened or postponed.

Anorganic pollutants (heavy metals) have also been studied in the sea water, sediment and organisms. The sudies of mercury ecological cycle in the sea show the Kaštela Bay to be heavily loaded by mercury at different trophic levels and particularly in sediments. The mercury emission stopped in 1990 and the autopurification of the bay has been assessed at 10 to 15 years on the basis of a model system.

The mercury accumulation has been observed in vital organs of angler to see the changes provoked after different time of exposure to different concentrations of mercury chloride. Kidneys accumulate the highest and blood the lowest mercury quantities.

In cooperation with the "Jožef Stefan" Institute in Ljubljana a method of observation of elementary mercury and its vapours effects on professionally exposed staff has been developed.

Furthermore, a method of analysis of trace elements - bromide in sea water has been developed in cooperation with the "Ruđer Bošković" Institute, Centre for Marine Research, Zagreb.