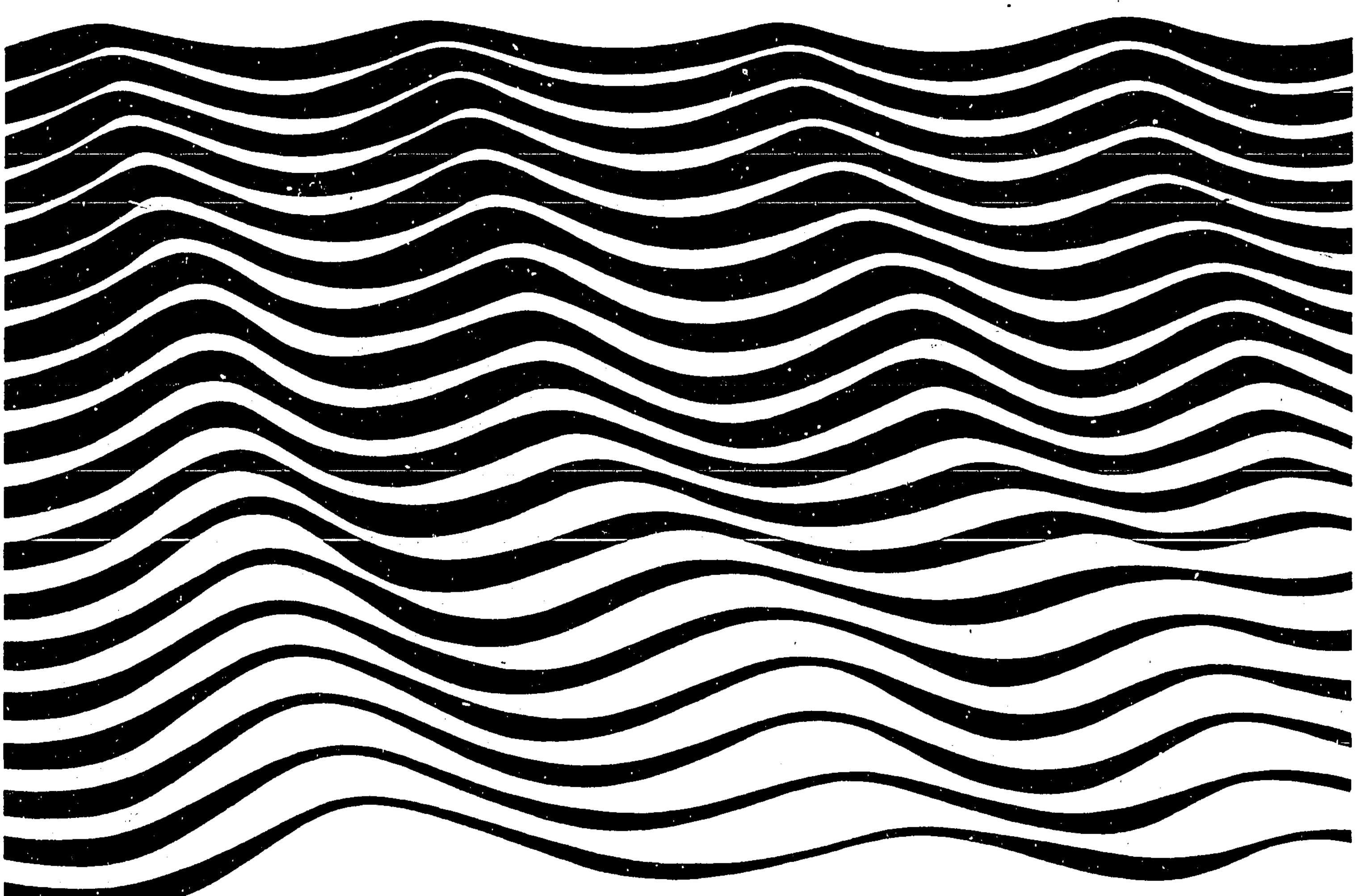
Unesco reports
in marine science 1

Marine ecosystem modelling in the Eastern Mediterranean

Report of a Unesco workshop
held in Alexandria, Egypt



Unesco 1977

PREFACE

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Unesco Reports in Marine Science* are issued by the Division of Marine Sciences as a complement to the series Unesco Technical Papers in Marine Science, which was first begun in 1965. The Reports series includes policy documents, meeting reports and material limited to specific geographic or project needs. They are distributed according to the subject area of each title and individual requests may be sent to the address found below.

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I. INTRODUCTION

The Eastern Mediterranean has unique characteristics compared with other semi-closed seas in arid zones. In order to reach the Eastern Mediterranean, the Atlantic water must pass through two straits, those of Gibraltar and those of Sicily. In both straits, water of lower salinity flows in, becomes more saline, and flows out as a subsurface current. Consequently, the Eastern Mediterranean is supplied by more saline and warmer water than the Western Mediterranean. Nutrients are lost with this circulation pattern, arriving in relatively low quantities in the surface inflow, and existing in slightly higher quantities in the bottom outflow.

Hence, the processes that cause the Western Mediterranean to have higher salinities, higher temperatures, and lower nutrients than the Atlantic occur again in the Eastern Mediterranean, making it differ significantly in these quantities from the Western Mediterranean.

From a biological point of view, the benthic communities in the east show the effect of their isolation. Although they were colonized from the west, they are now distinct, having less affinity to Atlantic communities than those in the west. Thus the Eastern Mediterranean can be regarded as a secondary sea of the Western Mediterranean, which is, in turn, a secondary sea of the Atlantic Ocean.

Civilization has been expanding around the Mediterranean Sea for over 5,000 years. However, it was only about 100 years ago that human activities started to introduce recognizable environmental and biological changes in the Eastern Mediterranean.

Although its implications were not fully realized at the time, a large-scale ecological experiment started with the cutting of the Suez Canal in 1869. This linking of the Red Sea and the Mediterranean Sea has resulted in extensive biological changes in the Levantine Sea as a result of the migration of plants and animals through the Canal. Together with the Straits of Bosporus and of Sicily these are the only pathways for the migration of marine organisms to and from the Eastern Mediterranean.

Construction of the Aswan High Dam has introduced another pattern of hydrological and biological change. The subsequent reduction of freshwater and nutrient input has caused, in a short time span, drastic changes in the water properties and in the regional productivity. The Eastern Mediterranean is so strongly oligotrophic that the fish stocks are much more sensitive to recent increased fishing pressure than in oceanic coastal areas or in other seas. Urban waste disposal and river-borne contaminants are affecting an ever-increasing portion of the coastal region, and the role of bottom water formation becomes even more important, particularly in such polluted areas as the Northern Adriatic.

Moreover, the Eastern Mediterranean is the main route along which oil passes from the Middle East to Europe. As the volume of transported oil has increased, huge amounts have already been released or spilled in the sea, and the chance for even greater damage grows as ship traffic increases. Thus the natural ecological balance is changing in the Eastern Mediterranean as a result of the combined effects of reduced nutrient input, immigration through the Suez Canal, pollution and overfishing.

All these man-made changes offer a unique opportunity to analyze ecological processes on a dramatic scale. Modelling studies provide an efficient means for understanding a regional ecosystem and its productivity. They can also provide a valuable basis for the prediction and interpretation of the effects of similar large-scale human activities in other parts of the world.

For this reason, the Unesco Division of Marine Sciences regards the Eastern Mediterranean as an ideal place for interdisciplinary research and cooperative investigations. The collection of data relevant to an ecosystem modelling effort would not only serve as an input to the large-scale model, but would assist in the development of regional coastal models. Certainly the Eastern Mediterranean is a natural laboratory which should be exploited for studies in international ecosystem management.

Workshop Organization

During the IBP/PM-Unesco Symposium on the Eastern Mediterranean Sea held in Malta in September 1973, an action plan for a long-term multidisciplinary scientific investigation of this area was formulated and fully endorsed by the participating scientists. It calls for strengthening marine science and facilitating the exchange of the scientists and data in the surrounding countries.

As an outgrowth of this interest in modelling, Unesco proposed to support workshops on the subject among regional countries. The University of Alexandria hosted the first workshop, wherein attention was focused on 1) utilizing the Egyptian coastal zone as a specific example for the construction of a subsystem model, and 2) formulating priorities and requirements for a general Eastern Mediterranean Model.

The participants in the first Eastern Mediterranean Modelling Workshop included specialists invited by Unesco, Egyptian marine scientists, regional participants from other Eastern Mediterranean countries, and individual marine scientists invited in their personal capacity. Although the Egyptian coastal zone was the principal focus of this workshop, plans are being made for future workshops which would deal with modelling in other Eastern Mediterranean subregions.

Initially, in order to familiarize the participants with the area, reviews of the physical, chemical, biological, and geological oceanographic research carried out in the Eastern Mediterranean were prepared prior to the workshop by Egyptian marine scientists (Appendix II) and then presented to the workshop participants (Appendix VI). Lists of selected references (Appendix III) and individual bibliographies supplemented this introduction to the region. Marine science research in Egypt has been carried out through the Oceanography Department at the University of Alexandria and the Institute of Oceanography and Fisheries.

Following this introduction and orientation, the workshop broke into four topical groups on the basis of the background and research interests of individual participants. Each group included the participation of Unesco specialists, and dealt with one of the major components and processes in the individual systems, namely:

1. physical oceanography: circulation, mixing, water mass analysis, and meteorological inputs;

2. geological oceanography: sources and sinks for sediment including pollutants, transport processes, and coastal zone interactions;

3. chemical oceanography-primary productivity: nutrients, phytoplankton, and zooplankton, production and consumption, fisheries; and

4. biological oceanography-benthic ecology: nutrient regeneration, bottom community structure, pelagic-benthic interaction.

These groups constituted the working units and each was responsible for considering the dominant inputs, outputs, processes, and interactions involved in their subsystem. From these discussions, each group formulated a conceptual model of their system within the Egyptian coastal zone, which was then presented to the entire workshop. The models were refined and inter-related giving each participant the opportunity to evaluate the components of each model and to understand their interactions.

The workshop discussions at this point were broadened to include the entire Eastern Mediterranean. Representatives from Lebanon, Libya, Malta, Syria and Tunisia presented brief summaries of the nature and scope of their marine research programmes (Appendix III).

Subsequent presentations, primarily by Unesco specialists, and discussions were directed towards the mechanics of model development. The individual stages and development of a model were presented using the entire Eastern Mediterranean as an example. A thorough treatment of the problems of data collection and standardization followed which focussed on the practical aspects involved in constructing models of the marine environment. The development of several specific models, and explanations and examples of numerical calculations, were all components of this session and were designed to facilitate utilization of modelling as a useful research tool.

The workshop terminated with presentations and discussions of specific proposals directed towards future efforts involving modelling in the Eastern Mediterranean.

Workshop Report

During the workshop, a consensus evolved among the participants that some formal preservation should be undertaken of the information and views which were being exchanged. It was agreed that more than just a summary report was needed. A publication was required which could serve the dual purpose of 1) assembling the information and ideas exchanged into a scientific format, and 2) providing a reference guide to the topic of marine modelling with the Eastern Mediterranean as an example.

Dr. Morcos offered to sponsor and promulgate the report within the series Unesco Technical Papers in Marine Science. Dr. Hopkins, as Chairman of the workshop, assumed the editorial responsibility, with the main contributions coming from the other Unesco invited experts, Drs. Griggs, Jansson and Wulff, and with Dr. Halim editing the Egyptian section. The contributions from other individual participants constitute significant portions of the report, in particular, those of Drs. Dowidar, Halim, M. Jansson, El-Maghraby, Sharaf-El-Din and El-Wakeel. The excellent administrative organization of the workshop, under the direction of Prof. El-Maghraby and his associates both from the Department of Oceanography of the University of Alexandria and the Institute of Oceanography and Fisheries was an essential factor in the success of the workshop.

II. CONCEPTS OF MODELLING

A. Definition

The purpose of modelling is to represent nature in some abstract language as accurately and manageably as possible. The word system is commonly used to identify that part of the natural world which we wish to model. Subsequent inspection of smaller components of a chosen system are referred to as subsystems. Just how we choose to represent a system becomes a question of methodology. By such a definition a model is merely a mechanism to describe a portion of nature in some format, be it mechanical, electrical, verbal, schematic, or mathematical.

Use of the word model has proliferated recently in the lexicon of the environmentalist towards a preference for the mathematical or computational type of description. We find in recent literature reference to hydrodynamical models, air pollution models, grasslands ecological models, and so forth, where the usage rather implies a mathematical description of the subject. The trend for computational (numerical) models should not be regarded as an effort to exclusively take the place of other alternatives, such as the numerical tidal prediction schemes superseding mechanical tidal machines, but only a reflection of the increased computational potential currently available. This is mentioned to underline a major objective of the workshop, that of demonstrating the value of conceptual models expressed verbally or schematically.

The restriction that a model can never be more realistic than nature itself seems to breed cynicism, or at least controversy, towards the exercise of modelling. Present models are far from realistic. Further criticism has been raised in that the simplifying approximations often required are so restrictive as to make them inappropriate. These are really questions of justification. Model construction must be considered as a complicated sequel to the scientific method. Many developments in marine science have emerged from a process of model construction. For example, the essential step of verifying modelled results with a natural system has led to progress in sampling methodology. Other examples of benefits accrued during model construction are developed within this report.

Certainly the most attractive potential for modelling lies in its predictive capability. In cases of strongly deterministic phenomena, such as tides, the value has long been recognized. The goal of extending a predictive capability to more and more phenomena is critical to the efforts of environmental modelling. Accompanying the value of prediction for prediction's sake is the capability for sensitivity or perturbation analysis, which can be regarded as an experimental tool to further understand the relative importance of the component subsystems and processes within the modelled system. This is a tremendous asset in handling problems of environmental management. Recent obvious alterations in marine ecosystems have led those involved in management to approach marine scientists for comment on the use of the sea for reasons of resource, waste disposal, and recreation.

The main scientific rewards involved in model application are those inherent in its construction. This is stressed by the workshop to diminish the notion that ecosystem modelling is beyond the facility of the less technically endowed countries or institutions. In fact the realization of a successful model should not be considered as some quantum breakthrough, but rather the result of careful dissection and reassemblage of a natural system, the completion of each step of which is essential to a comprehension of the final product. Looked at in this way models can be regarded as more than just descriptive mechanisms as first mentioned, but additionally, as powerful tools available to the scientist to be used in the exploration and comprehension of natural systems.

B. Selection of a system

The improper delineation of the system can easily be the first pitfall in modelling methodology. Traditional research along purely biological, chemical, physical, or geological lines is inadequate in the sense that nature does not necessarily observe these subdivisions. Many such models of strictly biological or other processes have their intrinsic value from a scientific point of view, but often are not directly applicable to natural systems modelling because the subject process is not sufficiently separable. For example, in the modelling of primary production both the biological process of photosynthesis and the physical process of light transmission are relevant.

In applied problems there is also a chance of difficulty when the modelling goals are set by other than scientific criteria. For example, an environmental agency may want a model of a certain coastline that is either a geographic or political entity, but lacks continuity in a natural sense. During the workshop discussions, it was suggested that the western part of the Egyptian coast (i.e., along the Nile Delta) was significantly different from the eastern part, and consequently should be modelled separately. It may be that the improper selection is not recognized until well into the modelling process, in which case, the modeller is obliged to re-define his subject system. Therefore, in addressing ecological problems marine scientists are finding it more useful to make divisions according to naturally occurring subsystems.

Thus appropriate subdivision becomes a very important facet of modelling methodology. Breaks between systems are best made where the coupling is the weakest. The criteria for weak coupling may be functional, spatial, or temporal. As a simple example, consider an automobile system. An analysis of the electrical subsystem as opposed to the braking subsystem would be a functional distinction; that of the right rear lamp versus the left rear lamp would be a spatial distinction; and that of wheel hub lubrication (to be done every 50,000 km) as opposed to front-end lubrication (to be done every 5,000 km) would be a temporal distinction. This approach would contrast to other possible types of analysis which might consider all gaskets, all copper parts, and so forth, as separate subsystems.

Functional distinctions are made on the basis of activity within the system, for example, that between organic and inorganic suspended matter, that between planktonic producers and consumers, or that between surface heating and surface evaporation. Functional separation becomes extremely important in process modelling, where the cause and effect relationships of small functional components of a system are studied. The results of process modelling are general and hence applicable to other systems.

Spatial distinctions are perhaps the most obvious. Much of the Eastern Mediterranean's uniqueness stems from its well-defined geographical separation from the rest of the marine system. Other distinctions are more complicated such as the photic depth, the spatial extent of which is not fixed but depends on the independent parameters of incident radiation and transmissivity of the water.

The difference in the time scales of natural processes also results in weak coupling permitting subdivision. Processes or components changing slowly with time can be considered independent of time with respect to those changing rapidly. Some examples of contrasting time scales are : a) phytoplankton biomass turns over within days, while some consumers require months; b) sea-level changes resulting from local wind set-up last from hours to days, while those from steric effects are more of a seasonal phenomenon, and c) planktonic eutrophication occurs within days, while benthic modification takes place on the order of years in the environs of a sewage outfall.

Considerations that must be weighted in selecting a system are the resolution and the coverage expected for the model. For a given facility the two are mutually exclusive, that is a large coverage is accompanied by low resolution. A model of the entire Eastern Mediterranean would not provide much information about individual coastlines, which might only be treated as a generalized boundary influence. On the other hand, a specific coastal model would focus on one locale and only approximate the boundary conditions connecting it to the Eastern Mediterranean. A large coverage model may treat a large system as a selected number of input-output relationships each including a series of processes, while a high resolution model would treat only a few processes in detail. The large coverage models are useful in management of an environmental system or as a tool to direct research. But, since they rely on many assumptions and are tuned to work in a best fit sense, they are often misleading in detail and of little predictive value. The resolution models are constructed on a best understanding of natural processes and should be constructed regardless of fit to nature, which makes them the more valuable from the standpoints of pure research and predictive capability.

C. Conceptualization

After a certain natural system has been chosen, it must be expressed in a form that can be easily communicated and utilized independently of the authors. This step is referred to as conceptualization, or qualitative description. This exercise often is treated as an inconvenience and done in a rather incomplete verbal way, corresponding, for example, to the prose introductions preceding models given in the literature in which the conditions and assumptions of the model are given.

In structuring the workshop to achieve one of its main objectives, that of constructing conceptual models of the Eastern Mediterranean and particularly the Egyptian coastal zone, the use of strictly verbal portrayals would have been unsatisfactory from the point of view of communication and expedience. Some form of schematic language was required, and H.T. Odum's so-called energy circuit language was chosen. Detailed definitions of this language are found in Appendix I. This format, although requiring some familiarization, is flexible enough to serve description regardless of coverage or resolution. The point, however, is more to stress the merit of the conceptualization procedure itself, particularly the point that, if carefully done, it reduces the probability of pursuing design-poor computational models or inappropriate field measurement.

D. Connecting conditions

Any selected system is always related to its environment, since there are no isolated or independent systems in nature. Among the criteria used for the selection of a system was that it be extracted from its environment at places of weak coupling. In so doing its connections are minimized in strength and/or number. Therefore, the connecting conditions specify how one system is related to another.

When the connection is from the modelled system to the external environment, it is referred to as the output. This is simply the consequence or solution of the modelled system. When the connection is from the external environment to the modelled system, it is referred to as the input or boundary condition. Usually the input is thought of as a forcing function, or an active connection driving the system from outside and often varying in space or time, as for example, the amount of solar radiation reaching the sea surface. The boundary conditions are often reserved to express the passive connections, as the reflectibility of the light reaching the bottom. The special case for the condition at the beginning of modelled time is called the initial condition, as the temperature of the water when the model began. These distinctions are mostly a matter of usage and need not to be discussed in detail here, the point being that these are the connections specified at the dimensional periphery of the system. Finally, two subsystems may be connected through an interaction connection. Interactions are considered internal, even though in some cases they may relate the output with the input.

Returning to the automobile analogy used earlier, let us choose the distributor as a subsystem of the automobile electrical system. We can imagine the wire from the coil as the input, and the wires to the spark plugs as the output. The amount of current in the primary circuit and the rotor speed we might classify as boundary conditions. Fig. 1 depicts this in energy circuit language. In terms of selecting the distributor as a component to study, we recognize these connections as obvious points of coupling. If instead we considered the engine system, these connections to and from the distributor now become interaction connections. A change in engine speed changes the distributor performance and hence the output, and so forth.

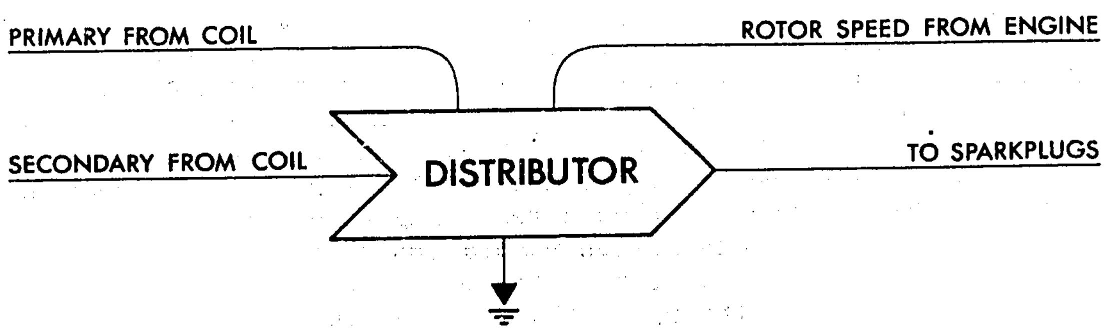


Fig. 1 Workgate symbol for an automobile distributor.

The sensitivity of a system to its external connections varies. Fortunately we need only to concern ourselves with the stronger points of coupling, depending on the degree of accuracy we want in the output. For example, if we were modelling the salt content of the Eastern Mediterranean, the major connections are laterally through the straits of Sicily and vertically through the sea surface. Other connections through the Dardanelles, the Suez, the Adriatic and Egyptian runoffs are minor, and still others might be considered negligible. The output of the system may or may not be sensitive to its boundary conditions. For example, the production of a phytoplankton bloom is not sensitive to the original population of phytoplankton, but it is sensitive to the original population of zooplankton. The amount of dissolved O_2 and CO_2 in the surface water is much more sensitive to the atmospheric concentration of O_2 than that of CO_2.

The system is also sensitive to the type of interaction connections it may have internally. Three types of interactions are shown in Fig. 2 (page 12) : part a shows a simple series connection of phytoplankton and zooplankton; b, a simple parallel connection between the phytoplankton species; and c, a nonlinear connection between the process of photosynthesis and that of light absorption. Thus the success of our model will depend strongly on an understanding and correct assessment of how our system is connected externally to its environment and how it is connected internally between component subsystems.

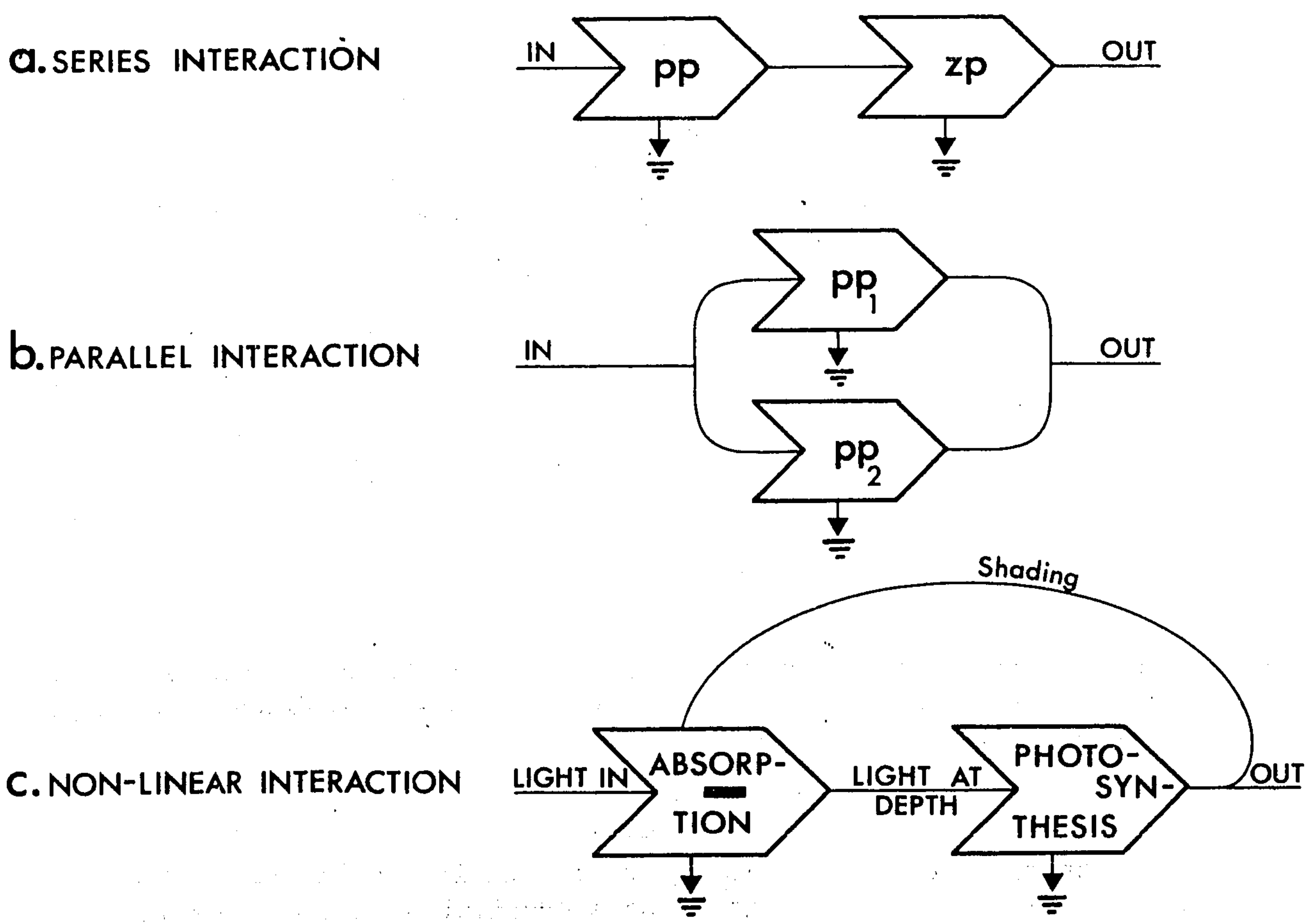


Fig. 2 Types of interaction conditions

E. Formulation

If a model must be quantified, the final steps of formulation and computation are needed. The exercise of formulation translates the problems from a schematic, verbal, or other conceptual format into a mathematical language. Formulation involves the derivation of a suitable transfer function that expresses the output in terms of the input as it is subject to the boundary conditions.

Just as compromises to authenticity were made in reducing the system to a conceptual model and describing the connecting conditions, even more are made in this step of formulation. Great attention must be paid to the behaviour of the mathematical expressions versus the behaviour of the natural processes they represent. Usually this involves restricting the formulation to certain dimensional bounds, for example, a linear growth curve during certain times, and paying close attention to the relative magnitude of various processes, boundary conditions, and interactions. That is, for a first approximation, only the major terms and conditions are formulated. Often the system may be judged insensitive to a dimension, as with steady state models, and thereby implied.

The process that must be formulated is known either to obey a certain physical law, is to be approximated by an empirical law, or is not understood. If it is not understood, we can make the probable assumption that the process under consideration has not been sufficiently subdivided, since we assume that ultimate subdivision will return us eventually to a known law. In this case the discussion has returned to the distinction between coverage and resolution mentioned earlier. If certain processes cannot be properly formulated or must be lumped together, this then constitutes a sacrifice of resolution in favour of coverage. It may turn out that the model is not sensitive to imperfections in some of its constituent processes. If a model is correctly formulated in all but a few processes and the input-output data are verifiable, then the modelled output can be used to better approximate the formulation of the unknown processes.

To briefly illustrate the step of formulation, we shall discuss several hypothetical examples. Perhaps most common are linear relationships, meaning that the output is proportional to the input. The proportionality may be a dimensional conversion or a scale factor. If the zooplankton biomass (Z) were appropriate to that of the phytoplankton biomass (P), the formulation for the grazing process would merely be:

$$Z = kP$$

where k would be a dimensional constant. If we wished to express a generalized loss process for phytoplankton so that the loss was always a fixed percentage of the population, then the formulation would be:

$$P_{out} = \gamma P_{in}$$

where γ is a loss scale factor. Although a process is not linear over its entire range, it may become increasingly so approximated as the range of the independent variable decreases. Large coverage models often make ample use of linearization in the hope that either process is linearly valid over the range or interest and/or that the system output is not sensitive to an erroneous linearization of a component process.

Another common formulation occurs when the gradient of a quantity is proportional to itself. Thus if we wish to formulate the process of absorption of light by this law, then

$$\frac{dI}{dx} = -\alpha I$$

where I is a light intensity and x a distance. This can be re-expressed as

$$I_{out} = I_{in} e^{-\alpha x}$$

to comply better with our schematic representation. Again as in the linear cases, many processes may be expressed in this simple exponential formulation only over a certain range, out of which the approximation is invalid. If the growth rate of phytoplankton were proportional to the population, the growth would be exponential; but if the constant of proportionality changed (i.e. reduced) drastically due to an extraneous dependence (nutrient availability) then the exponential growth would no longer be valid (bloom die off, etc.).

Of course many natural processes require more complicated formulation arising from relationships involving higher order differential equations, non-linearity, and so forth, extending beyond the scope of this exposition. The solution of the differential equation may be thought of as a transfer function giving the functional dependence of the output in terms of the input. The cases where the transfer function can be found through exact or approximate mathematical solution are referred to as deterministic. The transfer function for some non-deterministic cases can be statistically found on the basis of empirical correlations.

F. Computation

This final step involves the numerical evaluation of the model. The methodology depends on the complexity of formulation, the extent of the input and output values to be manipulated, and the computational facility available. Pursuing any sizeable modelling effort today necessary requires the use of an electronic computer. However, spot checks, order of magnitude analysis, and other computational short-cuts should be employed prior to or concurrent with detailed computational programming.

For high resolution models with complicated transfer functions or connecting conditions, the primary difficulty often involves solutions through analytical approximations, numerical analysis, and so forth. For large coverage models the difficulty often arises in the solution of large numbers of simultaneous equations corresponding to the number of unknown outputs to be computed. Although often difficult and expensive the computational step is perhaps the most straightforward, except when such techniques are used that might generate computational errors extensive enough to invalidate the model. The reader is best referred to the literature for the computational technique suitable for his application, Appendix IV.

A. Energy circuit language

In order to communicate the conceptualization of a model, some kind of language must be used. A strictly prose model, using English or Arabic, might be employed to describe the model and its different variables and flows. However, this could be too long or unclear. As an alternative, one might supplement the prose description with mathematical terms, using for example, time-dependent differential equations. This is often a more precise and shorter means of description and eventually becomes a necessary step, if the model is to become quantified. (See Section III. G).

For most people it is difficult to visualize a system from a set of equations. A convenient step between a prose model and a mathematical model is a picture model, wherein the different variables and their connexions are visualized by symbols. For example, this sort of language is found in Forrester's "Dynamics".

We have used extensively H.T. Odum's "energy circuit language" in our modelling work and found it quite adaptable to both systems of man and nature. The energy circuit language has a mathematical background (Odum, 1972), but it can also be used for pure description. It is a very simple language where the different properties of a system : forcing functions, state variables, processes, flows, are translated into boxes and lines of different shapes. This permits a quick comprehension of the character of the system in a manner which is easier to follow than a set of equations. The different symbols are presented in Appendix I, which is borrowed from Lugo et al.(1971).

By way of an explanation, we now will describe the procedure and symbols used in the construction of a simple marine systems model. One of the first steps is to define the limits of the model both in space and time. Shall it represent a bay or the whole Eastern Mediterranean Sea ? Does it incorporate the whole water column and the top few centimetres of the soft bottom ? Is the time scale one season, e.g. a spring bloom, one year, ten years ? The next step would be to list the different variables of the system and to decide which ones are driving the whole system. The driving or forcing functions are usually large energy sources such as the sun, run off from land, tides and waves, each often with a distinct periodicity. Next come the state variables and their connecting processes. As a general rule one should try to model two steps beyond the problem one is interested in, in order to secure the necessary dynamics of input and output functions. If one, for example, is interested in nutrient kinetics one should incorporate both solar radiation and the feed-back to the nutrient pool by the action of the consumers and bacteria.

The main forcing function driving the marine system is the sun, which is depicted as a circle. For modelling a whole year cycle it should be represented by the annual insolation curve, or simply a sine wave (Fig. 3). One of the main variables within the system is the phytoplankton, the producers. A bullet-shaped symbol shows their place in the model. They are self-maintained "machines" and have to put a great deal of their captured energy into maintaining the elaborated organization of linked processes such as feeding, growth, propagation and repair of worn-out tissues. This is symbolized by the downward arrow with the heat sink, which is equal to the respiration costs of keeping this living structure. But the phytoplankton do not only need the sun's energy; they also need minerals such as carbon, nitrogen, phosphorus. Carbon in forms such as CO_2 is in excess and seldom a limiting factor. It can therefore be left out from this simplified model for the sake of clarity. The other two can be lumped together in this overall picture and as "nutrients" be represented by the storage symbol, which indicates the location in the system of shared amounts of potential energy and matter. The process of fixing the radiation energy, the photosynthesis, is symbolized by the pointed block symbol, the work gate. The flow of one kind of potential energy, the nutrients, are making the inflow of another, the light energy, possible. In a mathematical translation this process can either be simplified by a multiplicative function or given a more elaborate form, for example an expression of Michaelis-Menten kinetics (Monod equation). As in every spontaneous process energy is "lost" as heat, according to the second law of thermodynamics, and this is shown by the arrow and a "ground" symbol from the work gate. Though not shown here, the producer symbol contains a "storage" symbol that represents biomass, and a "work gate" that represents the processes involved in the metabolism. This is described in greater detail in Section III. G.

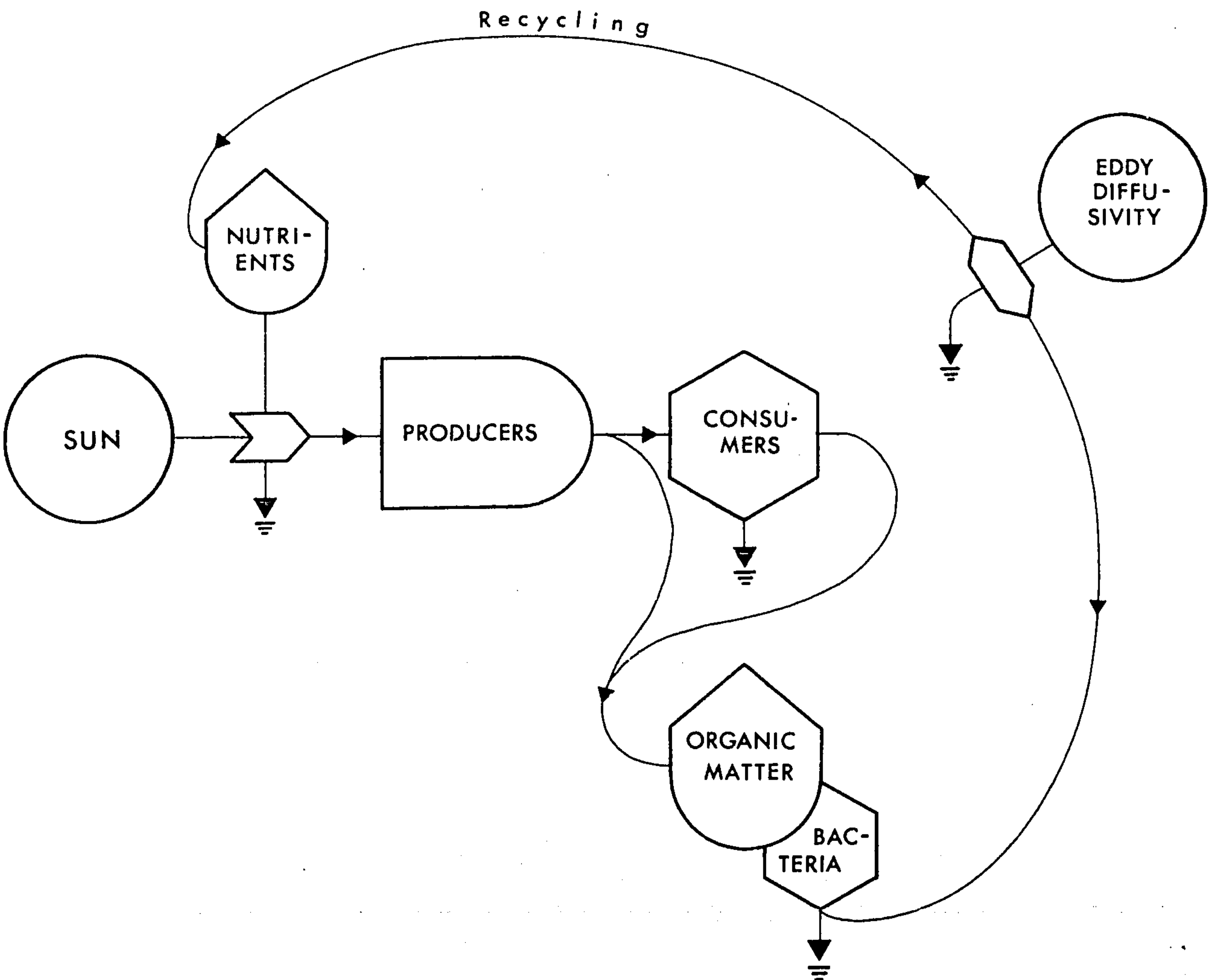


Fig. 3 The main features of a marine system.

The hexagon is a consumer symbol and consists in this case of the total amount of consumer organisms in the pelagic system. The line from the producer symbol to the consumers represents the feeding of the herbivores. In this over-simplification the consumer symbol in fact is a condensation of herbivores and carnivores of different trophic levels. The heat sink represents the total cost for maintaining the necessary structure, i.e. the respiration. The excretion of energy-poor substances during the respiration process, such as urea and feces, contains some of the nutrient salts necessary for plant growth. It therefore constitutes one of the numerous positive feed-back loops that are so important to the living systems, and which give them their various characteristic time scales.

When the pelagic plants and animals die they sink to the bottom as particulate organic matter. The lines from the producers and consumers therefore symbolize the process of sedimentation. The pool of organic matter is shown by the storage symbol. The dead organic matter is immediately attacked by bacteria. In the process of converting the energy-rich compounds to energy-degraded substances, the bacteria build up their biomass. Therefore, the bacteria are also consumers and, with respect to their short turn-over times, very powerful ones. They are closely connected to the organic matter, which is visually shown by the merging of a consumer symbol into the organic storage symbol as in the figure. The nutrients from the mineralization processes reinforce the positive feed-back loop of the other consumers.

The structure of the pelagic system has a vertical dimension. The production is concentrated in the surface layer, whereas the decomposition (respiration) dominates in the deeper layers. The phosphorus and nitrogen compounds necessary for plant growth, as a consequence, show a pronounced vertical gradient and the rates of the feed-back flows are critical for the maintenance of the system. Here the physical processes play a most important role. In the model they are simplified to a forcing function simulating the vertical exchange, here called "eddy diffusity" which operates a two-way gate. This means that the flow can go in either direction depending upon the concentration differences of the nutrients.

This basic model is presented purely as an example of the use of the energy circuit language. It can easily be translated to mathematics. The way in which this is done is shown in section III. G.

B. Eastern Mediterranean summary model

Modelling of the Eastern Mediterranean system should begin from a macroscopic point of view with special attention to the main forcing functions. Fig. 4 is a rough suggestion of how this could be done without aspirations of completeness.

The total water mass of the Eastern Mediterranean is divided into three boxes : the surface layer down to 200 m, the intermediary layer to about 600 m and the transition and deep layer below. The bottom areas of the two first zones are shown by the lateral displacement of the boxes. Neither volumes nor areas are drawn to scale. The forces acting upon this system are mainly

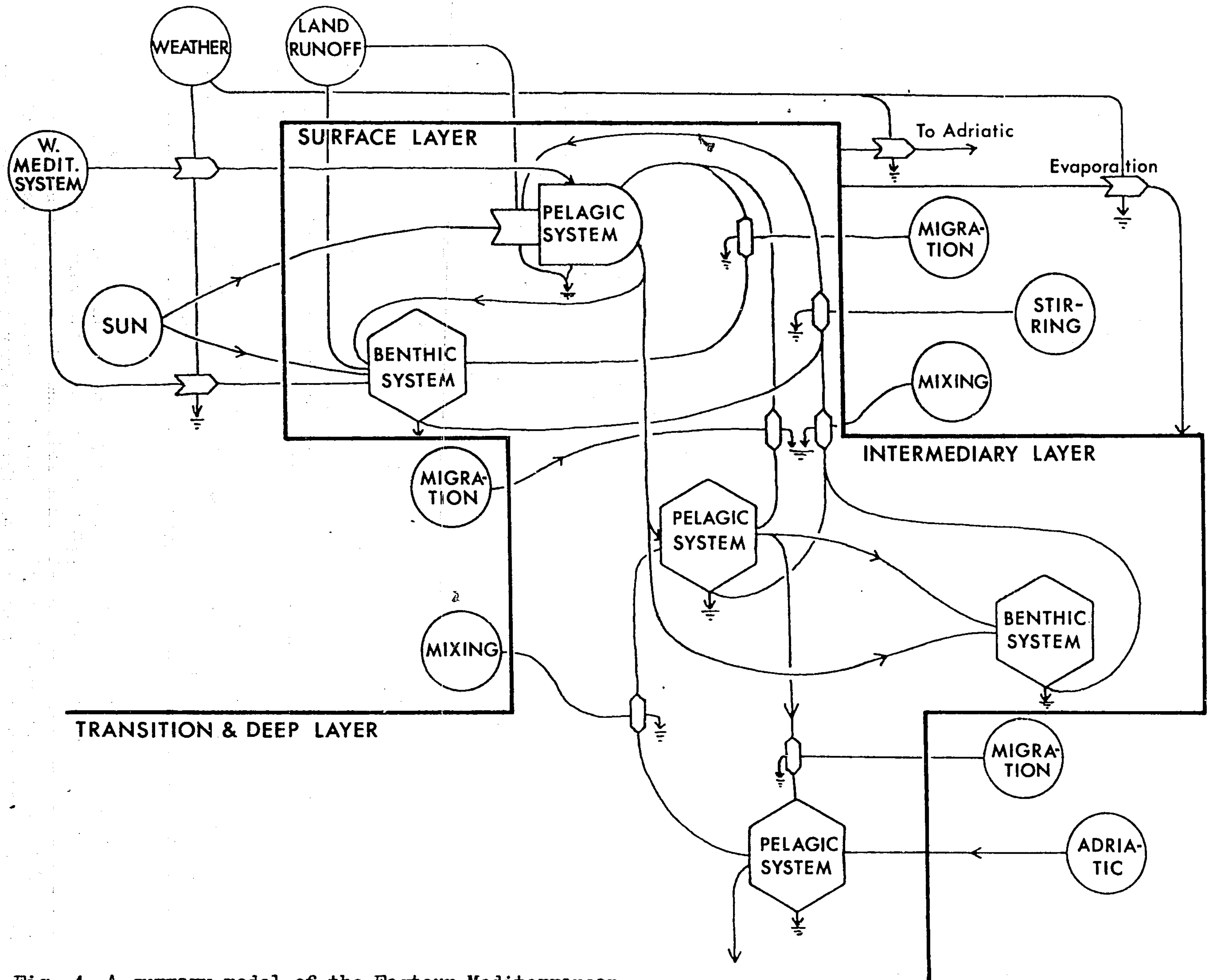


Fig. 4 A summary model of the Eastern Mediterranean.

of hydrodynamic character. For the sake of clarity they are here shown merely as indications without dissecting them into the primary processes which tie them all together. This is done instead in the physical chapter (III.E).

Driven by the atmospheric conditions, in which insolation plays a main part, Western Mediterranean water is forced into the eastern part. With it come not only physical or chemical properties but also organisms that supplement the pelagic and the benthic systems. Part of the Eastern Mediterranean water is forced into the Adriatic Sea. Another part is increased in density by evaporation and sinks to the intermediary layer.

Water from small basins and rivers and land runoff affect both pelagic and benthic systems with their different properties, such as contents of silt, organic matter, nutrients and toxic substances. This is shown in greater detail in the subsystem models. The transport and exchange between the three water masses is shown by the two-way gates operated by mixing forces. Within the surface layer stirring agencies are responsible for the exchange between the benthic and pelagic systems of seston and chemical matter. The deep layer receives water from the Adriatic Sea which is shown here as a transport to the pelagic zone.

If the physical forces have been oversimplified in this attempt to depict the Eastern Mediterranean as a whole, the biological variables are still more condensed. In the surface layer the following subsystems have been lumped into two systems : a) the free waters with their characteristic organisms from microscopic phytoplankton and zooplankton to fish, b) the hard bottoms with their luxuriant epifauna and flora, c) the sand and soft bottom with their economically important Posidonia meadows. The pelagic system is comprised of the organisms, all their processes, and their connecting storages tying the various plants and animals together. The model shows only the solar radiation and the uptake of nutrients, whereas in fact all the interactions between food-chains and their biogeochemical cycles are implied. Because of the dominant role played by primary producers, the phytoplankton, the pelagic system is indicated by a producer symbol. The waste products from the pelagic system such as dead organisms, fecal pellets and exuviae sink to the surface layer bottom, comprising the main energy source for its benthic system, or sink to the intermediary layer, where it feeds both its pelagic and benthic system. On its way down the organic matter is successively decomposed by bacteria. The soluble resulting products, such as inorganic nutrients, might reach the superficial layers by mixing processes. Other inflows to the pelagic system of the surface layer come from the Western Mediterranean, other adjacent basins and the land runoff (incorporating all the sewage flows summarized in section III.D). The flow from the benthic system symbolizes both the immigration of larvae from the benthic species and the seasonal migrations of nekton such as fish. (A more detailed version of the pelagic system is shown in section III. F).

The benthic system of the surface layer contains both the primary producers such as the important Posidonia beds, and the consumers, such as grazers, filter feeders and carnivores. The substrata and the processes affecting it like erosion and sedimentation, play an important role in this layer. The various storages and processes that tie this consumer system together are shown in section III. C. In this overall model, only the decomposition of organic material and distributor of inorganic nutrients are shown.

What sinks out from the Surface layer becomes the energy input of the Intermediary layer. The pelagic system is here a consumer system, mostly running on organic material, including bacteria. Diurnal and seasonal migrations both to the Surface layer and to the Transition and Deep layers occur. Migration patterns that differ between species, here are symbolized by a single forcing function. The formation of low energy compounds of the pelagic system such as inorganic nutrients is important in a decomposition system. The bacteria plays the main role, disentegrating both the yet undissolved particulate organic matter from the Surface layer and local products from plankton and nekton. Part of the latter continues to sink to the intermediary benthic system and further down to the Transition and Deep layers. Some of the inorganics formed in the Intermediary layer may return to the Surface layer through inmixing by physical forces.

The benthic system of the Intermediary layer contains practically no primary producers. Those of its large-sized consumers, that might constitute part-time components of the surface layer through migration, are judged to be small and are not indicated in the model.

In the Transition and Deep layers only the pelagic system is represented, which is driven by organic matter from the upper zones. The deep Adriatic Sea also inputs into this layer.

The benthic part has been omitted partly for the benefit of clarity, and partly because of its restricted communication with the intermediate zone.

To summarize, this total macroscale model should give an idea of the combined physical and biological processes. The small-scale processes are mainly incorporated in the subsystem modules and the larger ones utterly simplified by only indicating the major flows. It should be emphasized that this macro-model is only one possible representation of the system. It assumes an even distribution in the horizontal and vertical plans of the constituents of each layer. Despite simplicity it is still possible for the experienced scientist to see the diversified structure behind each simple symbol. For example, one can see how the solar radiation and the meteorological parameters drive the hydro-dynamic forces to large scale transports horizontally and vertically. Superimposed on these patterns are the pulses of the biological system, the diurnal ones, such as the intense fixing of carbon during the light part of the day and the consumption of the organic matter storage at night by respiration, and the diurnal migrations within and between the different layers of plankton and nekton. Superimposed on these pulses are the seasonal cycles both of production-respiration, and of migrations of plankton and fish.

Keeping the total model in mind, submodels may then be constructed not only of different organism systems but also of different sub-areas of the Eastern Mediterranean. In another type of total model their complexity might be condensed to one or two symbols connected to the rest of the total system by the dominating flows. This total model would then show the relation of different sub-areas to the whole. For example, it might turn out that one area distributes nutrients, whereas another area builds up and stores large biomasses of benthic organisms. Such examples are given in Odum (1967).

C. The benthic subsystems

The shallow sedimentary bottoms along the North African coast offer important fishery grounds to the different nations that exploit them. Attempts to estimate the density of the fish population by means of echo-integrators, have shown that heavy stocks are strongly correlated with the vegetation belts. The under-water meadows of Posidonia growing on sandy bottoms are particularly rich in species and have been the subject of thorough ecological studies. Large, sandy bottom areas outside the Nile delta were formerly covered by this vegetation. After the construction of the Aswan High Dam, the input of silt and sand to the bottoms has ceased and much of the sandy areas are being gradually covered by clay sediments with different biological communities. The Caulerpa community is probably less important for the production of sea food than is that of Posidonia. The marked decrease in the fish yield at the Egyptian coast, that has taken place during the last decade can partly be explained by these and similar changes of the bottom communities. The model of the benthic system is presented here in both a naturalistic format (Fig.5) and in the energy circuit language (Fig. 6). The aim is to illustrate how the flow of energy to the bottom is captured and used by the organisms and how the outputs from the system of e.g. fish are determined.

Description of the benthic model :

The model includes four main compartments, namely:

1. sediment,
2. bottom flora,
3. bottom fauna,
4. bottom fish and cephalopods (referred to as "sepia" in Fig. 6)

In addition, two separate storages are drawn representing nutrients and organic matter contents of the bottom water. The system is driven by radiation from the sun and by the hydrodynamic circulation. Interchange with the pelagic system is controlled by the vertical mixing of surface and bottom waters. For silt and clays and organic matter the net transport is downward and sedimentation is therefore shown as a oneway process.

1. Sediment

Two main types of sediment bottoms are included in the sediment module, namely the finer grained silts and clays, and the sandy bottoms. The supply of new sediments to the bottoms came at one time from the Nile water but is now derived from the eroding coastal line. Sediment is also transported away from the bottoms by the north-east drift (see Section III.). The pool of organic matter in the sediment which is broken down by the activity of bottom bacteria, is refilled by the sinking plankton organisms and detritus coming from the upper layers to the bottom water. In addition detritus from the seaweeds and from the bottom fauna (dead animals, exuviae, feces etc.) accumulates in the sediment. The flow of energy from the sediment to the bottom fauna by the feeding of scavengers and shrimps is shown as an out-flow from the organic tank. The nutrients of the sediment which are the end products of the breaking down of the organic matter are interchanged with nutrients

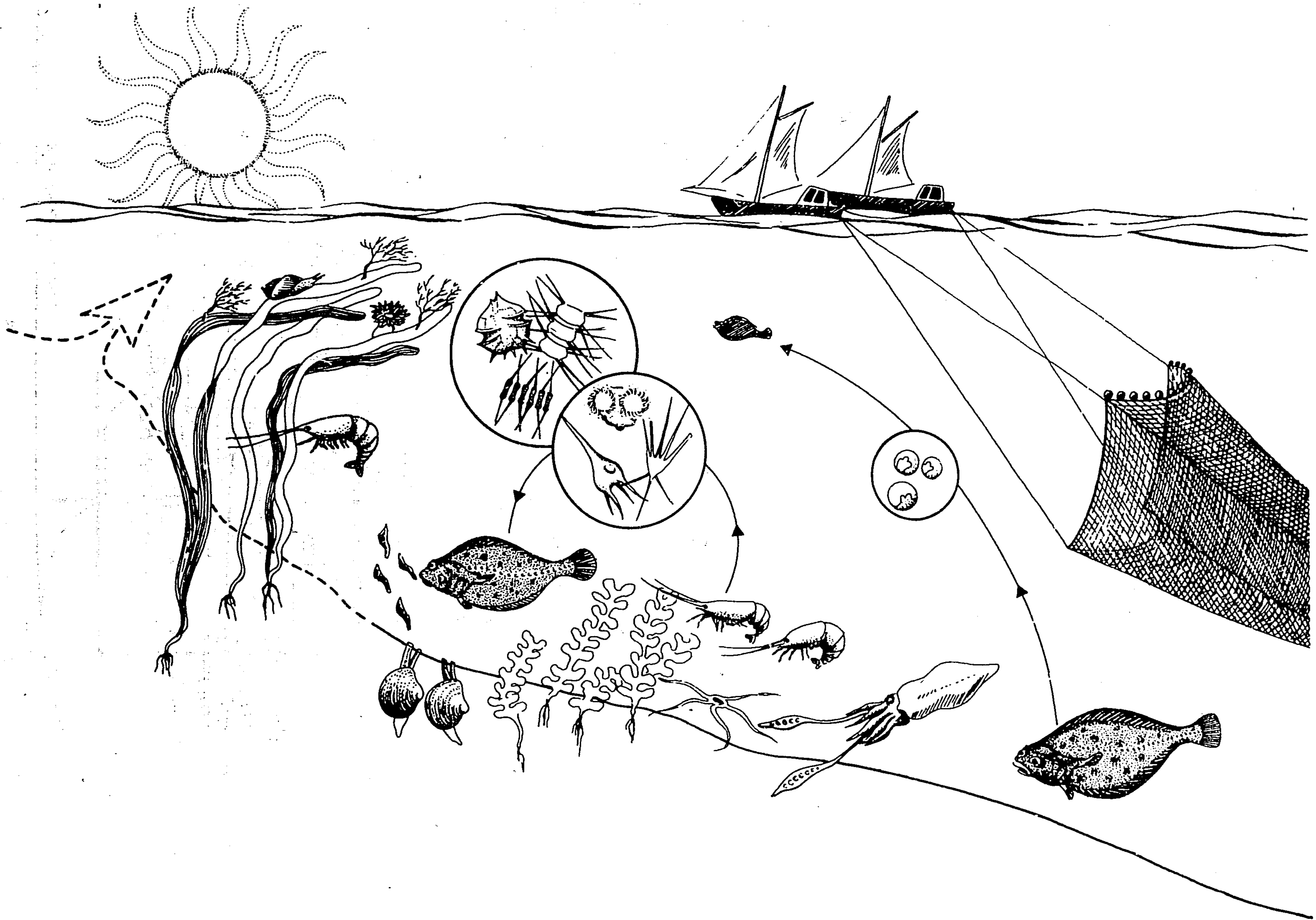


Fig. 5 A naturalistic picture of the benthic system, translated to energy circuit language in Fig. 6.

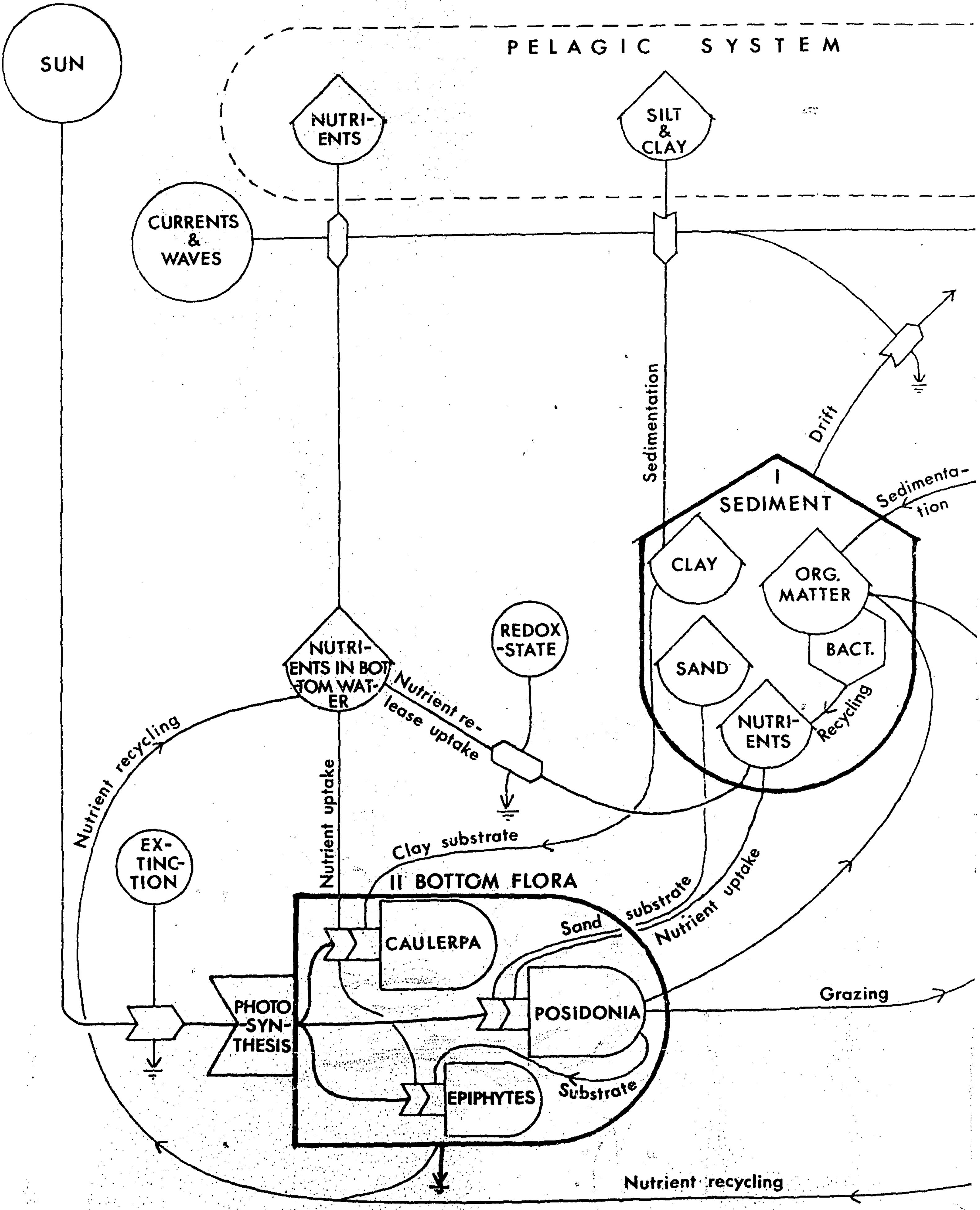
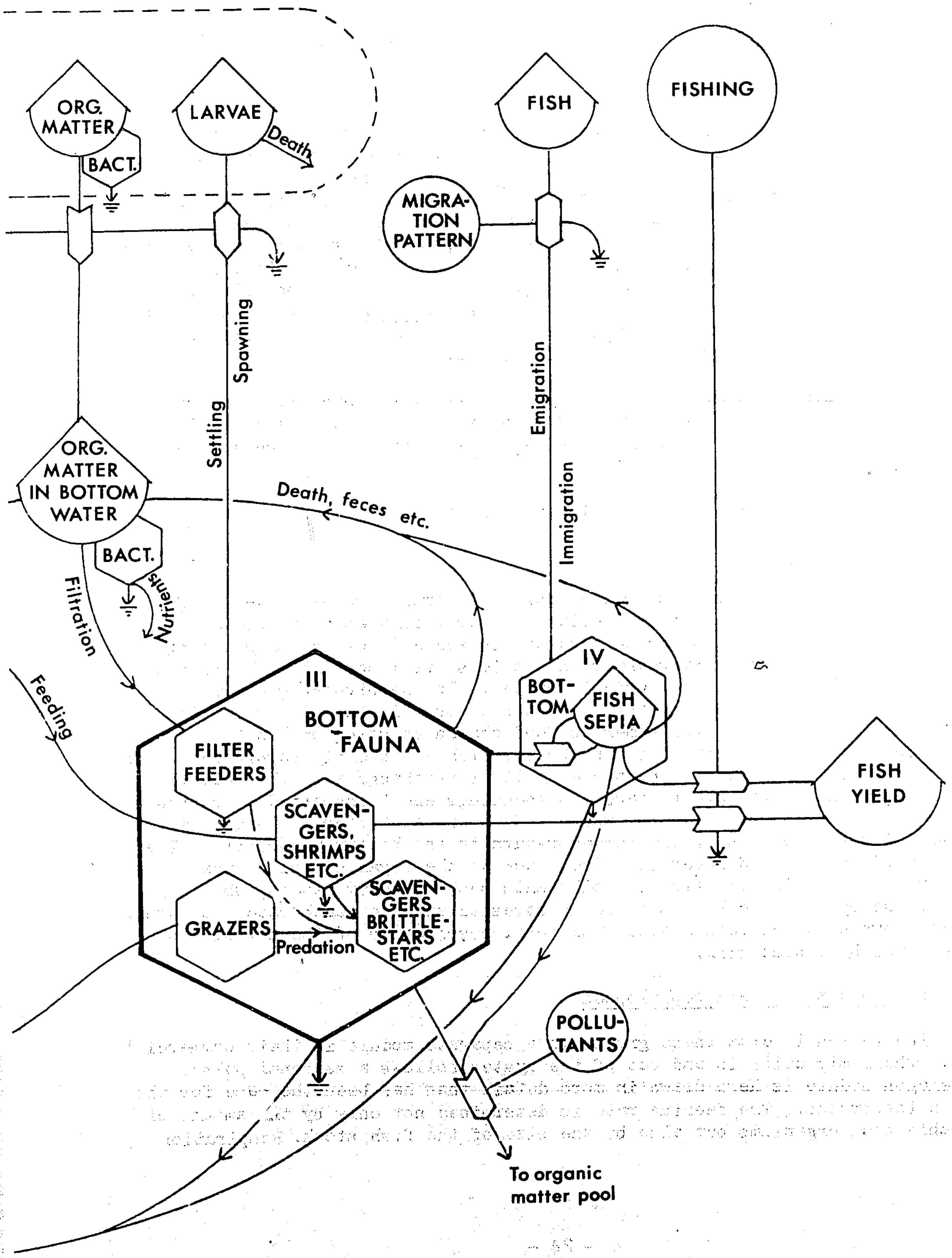


Fig. 6 A principal energy circuit diagram



of the benthic system of the Eastern Mediterranean.

in the bottom water. This process is controlled by the redox state of the sediment so that low oxygen levels at the sediment bottom interface will cause a release of nutrients from the sediment. Nutrients are taken up from the sediment by rooted plants such as Posidonia acting as nutrient pumps.

2. Bottom flora

Three main primary producers are specified in the bottom flora module. These are the Posidonia plants with epiphytic diatoms and filamentous algae and the gree alga Caulerpa. Sand is regarded as being essential for the growth of Posidonia while Caulerpa is bound to the fine grained sediments. The solar radiation available to the primary producers is determined by the extinction of light, which in turn is a function of water depth and turbidity (the amounts of silt and organic matter in the water). The rate of photosynthesis is determined not only by the intensity of light but also by the contents of different nutrients in the bottom sediment (as for Posidonia) or in the bottom water (as for epiphytes and Caulerpa). Furthermore the photosynthesis is regulated by the plant biomass as shown in Fig. 6.

The producer biomass is drained by the outflow of dead plant material and by the energy flow to the grazing macrofauna such as snails and small crustacea. The epiphytic flora is probably the most important food source for these consumers.

The total respiration of the producers is indicated by a heat sink.

3. Bottom fauna

This compartment is comprised of three different trophic levels. Food is derived from different sources. Filter feeders, such as clams and mussels, make use of the energy in the organic particles and also clean the water by their filtering activity. Scavengers and shrimps are important links in the breaking down of the sedimental organic matter. The herbivores graze the bottom flora. The predation by animals, such as brittlestars, is shown in the model as an example of the numerous food chains existing within the bottom fauna. Some of these terminate in the bottom fish and the big carnivores, such as cephalopods. The bottom fauna has a cyclic interchange with the pelagic system. Eggs and larvae are released at spawnings and transported by currents and advection to the upper layers, where they spend a shorter or longer period of time. A small portion of the larvae return to the bottom and settle. The flow of dead animals and feces is a feed-back to the organic pool of the sediments. By the introduction of pollutants such as heavy metals, DDT, PCB etc. to the system, the bottom fauna is stressed and the death rate increased. This is shown as a separate drain. The total respiration of the bottom flora is indicated by a heat sink.

4. Bottom fish and cephalopods

The reason to draw these groups in a separate module is their commercial value. Their migration in and out of the system follows a seasonal pulse. The hexagon module is here drawn in more detail than has been the case for the other heterotrophs. The feeding rate is determined not only by the amount of available food organisms but also by the size of the fish stock. Respiration depends on biomass and on the feeding activity. Death and production of feces is drawn as one outflow which is determined by the biomass only. Pollution stress is drawn as a separate drain regulated by the biomass and by the pollutants as a forcing function. The fishing activity is another outside force draining the biomass. The total fish yield is determined by the intensity of fishing and by the size of the fish stock.

The balance of oxygen is of vital importance to the whole benthic system. For the sake of simplicity, however, oxygen has not been included in the model. Oxygen is brought to the system from the upper water layer and is also produced by the bottom flora. All heterotrophic organisms together with the plants themselves and oxidating minerals in the sediment are then using up the available oxygen. Low oxygen levels occurring during the night might raise the redox layer of the sediment until phosphorus is released to the bottom water. The oxygen content might also in extreme cases sink to a critical level which kills part of the bottom organisms.

There is an interchange of inorganic nutrients between the bottom and surface layers through mixing processes. Nutrients are taken up by algae and recycled through the excretion by bottom animals but also leaching out from the bottom plants. There is also an interchange of nutrients with the sediment which is regulated by the redox-state of the bottom.

The organic matter reaching the bottom water from the surface layer is attacked by bacteria. During the decomposition process, inorganic nutrients are released and added to the nutrient pool of the bottom water. When the sinking organic particles reach the bottom, they become exposed to the greater decomposition processes of the sediment interface. By filtering the bottom water, different animal groups digest some of the organic particles. At the same time both animals and plants excrete dissolved and particulate organic compounds to the water. This and other feed back loops are important for stabilizing the benthic system.

D. Geological

The Nile River formerly was the major source of sediment for the entire Eastern Mediterranean Sea; measurements indicated about 57 million tons of material each year were being discharged by the river. The sand would settle out in the nearshore zone, where it would be sorted and redistributed by wave action, and then contribute to the littoral drift system. A west to east littoral transport system seems to predominate along the Egyptian coastal zone. The finer-grained silts and clays would be carried offshore and slowly begin to settle out as they were dispersed by prevailing surface and subsurface current patterns. Millions of years of sediment accumulation had led to a very fertile delta which was still outbuilding above sea level, and also a large submarine fan or cone. Clay mineralogy of recent Eastern Mediterranean bottom sediments indicates transport of fine-grained Nile sediment to the northeast along the coast of Israel, Lebanon and Syria.

Following the construction of the Aswan High Dam in 1965 the importance of the river as a sediment source declines to almost nothing. The annual flow has been reduced to less than 10% of its original volume; virtually all of the sediment carried by the Upper Nile therefore is trapped in the reservoir behind the dam. Any sediment now finding its way down the river or picked up along the way is trapped by one of the barrages near the outer edge of the delta. The result has been a halt in growth of the delta. Eastern Mediterranean wave action now is beginning to erode the unconsolidated delta sediments. This material has become a new, although considerably less significant, sediment source. Of the 250 km of delta front, approximately 1/3 is actively eroding, as is the coastline to the west, all adding both coarse and fine material to the sediment system. If not already occurring, this delta retreat will eventually begin to destroy valuable agricultural land.

The Nile was also an important source of dissolved nutrients and of much particulate organic matter as well. The Eastern Mediterranean has always been a nutrient-poor environment with only a few localized areas of nutrient enrichment : the Northern Adriatic, the Sarokinos Gulf, the Black Sea outflow, the area off Beirut, and the region off the Nile delta. The maximum nutrient values off the Nile delta occurred during autunm flood periods. Although the threshold nutrient values necessary to generate high productivity relative to the Nile input are unknown, productivity and consequently fisheries have suffered drastic declines due to a decrease in nutrient input following dam construction.

A wide variety of pollutants from many different sources enter the water with clay particles or organic detritus; evaporation, uptake by marine organisms or washing ashore onto beaches are some of the routes the pollutants may follow. Much of the information contained in the following discussion is taken from the report on the State of Marine Pollution in the Mediterranean and Legislative Controls prepared by the General Fisheries Council for the Mediterranean (1972).

Oil

The main sources of oil pollution in the Eastern Mediterranean are 1) loading and unloading of oil and its transport at sea, 2) the discharge of oily ballast water, still legal in two Mediterranean areas, one southwest of Cyprus, and the other between Italy and Libya (from this source alone it has been calculated that about 300,000 tons of oil are discharged annually), and 3) the effluents or leakages from refineries and storage tanks. Upon reaching the sea the more volatile fractions usually evaporate, and some oil is broken down microbiologically. The more resistant torry fractions may settle to the bottom or be wasted ashore.

Either on the bottom or on the coastline, the oil can be detrimental to marine life. For those Eastern Mediterranean countries where observations have been recorded, oil pollution is becoming a major littoral problem and it is difficult to find uncontaminated beaches.

Domestic wastewater

The domestic sewage from nearly 7 million people in Cairo and Alexandria enters the Nile drainage system and eventually reaches the sea. The total coastal population in the Eastern Mediterranean is about 22 million and most of the domestic sewage from these countries arrives at the sea untreated. Following the GFCM (General Fisheries Council of the Mediterranean) figures, the annual input amounts to 450,000 tons of biochemical oxygen demand (BOD) and 20,000 tons of phosphorus. The situation is particularly severe along the coasts of Lebanon and Israel. The table below gives a comparison of the sewage loading in countries around the Eastern Mediterranean. The nutrients in the effluents are added to the marine nutrient reservoir and stimulate primary productivity. The organic detritus is in part used by the pelagic organisms, another part settles to the seafloor where it can be utilized by the benthos, and the remainder is oxidized, removing oxygen from the water. The virus and bacteria in the sewage may transmit disease, affecting both marine organisms and users of coastal waters.

DOMESTIC SEWAGE LOADING

Country	Permanent Coastal Population	Annual	
		B.O.D. (tons)	Phosphorous (tons)
Yugoslavia	650,000	17,800	800
Malta	320,000	8,000	320
Greece	4,000,000	100,000	4,500
Turkey	5,000,000	100,000	4,500
Cyprus	480,000	9,000	430
Syria	260,000	6,500	260
Lebanon	1,250,000	31,250	1,250
Israel	1,600,000	32,000	1,440
Tunisia	1,650,000	12,800	540
Egypt	6,300,000	126,000	5,670
Libya	390,000	7,800	350
Total	21,900,000	450,950	20,060

Industry

Industrial wastewater from the paper mills and chemical industries of Egypt is discharged into the delta drainage system to find its way to the sea. The industries of the other Eastern Mediterranean countries, which include chemical plants, food production, metal industries and shipyards, textiles and tanneries, wood processing and paper, and mining operations, all contribute unmonitored volumes of various waste products to the sea as well. Heavy metals and acids appear to be among the most detrimental, with uptake of mercury, lead, and copper by marine organisms in even low quantities capable of producing acute or chronic toxicity. Fish kills, disappearance of commercial fish species, and changes of spawning grounds have been the most obvious impacts of industrial pollution on the marine life of the Eastern Mediterranean. In addition to biological uptake, metals can also be removed by particulate organic matter or clay minerals and settle to the sea floor.

Agriculture

Pesticides enter the Eastern Mediterranean from the surrounding agricultural area where their use is probably appreciable, either through drainage and runoff or evaporation and wind transport. Although figures unfortunately are not available, it seems likely that input of persistent chlorinated hydrocarbons to the waters surrounding the intensively cultivated areas of Israel, Lebanon, and the Nile delta is significant. There appears to be a growing tendency for increasing use of organo-phosphorous and carbonate insecticides in place of the persistent chlorinated hydrocarbons, which are cumulative and biologically magnified in the food chain. Several cases of fish mortality through inconsiderate use of pesticides has occurred in the region.

As organisms die, whether from natural or other reasons, they are added to the reservoir of organic detritus, either within the water column or on the sea floor. At the bottom this material becomes food for benthic organisms, or with bacterial degradation may be broken down further into nutrients and other components which then become raw materials for the primary producers again. The organic detritus on the seafloor can be consumed directly by scavengers, may be oxidized, or may be buried, in which case it may be later utilized by the burrowing-in fauna. If the bottom water circulation is restricted, oxygen depletion can occur, and a reducing environment with anaerobic decomposition is produced. In this situation, phosphate and ammonia may be released from the sediments into the bottom waters. With rapid rates of sedimentation, such as those which occur off the mouths of large rivers and on submarine fans, organic matter may be buried before breakdown is complete and therefore removed from the system. Depending upon the nature of the organic matter and its subsequent history after burial, it may ultimately be converted to fossil fuel, such as petroleum. The various marine pathways of these organic and inorganic materials are schematically represented in Fig. 7.

E. Thermohaline structure

Most of the physical processes occurring within a marine system are universal. The trick of model construction involves a proper selection of the dominant processes characteristic of a chosen system. The thermohaline response to meteorological driving forces plays a particularly significant role in the total dynamics of the Mediterranean Sea, even though the extent and effect of the response varies from locale to locale.

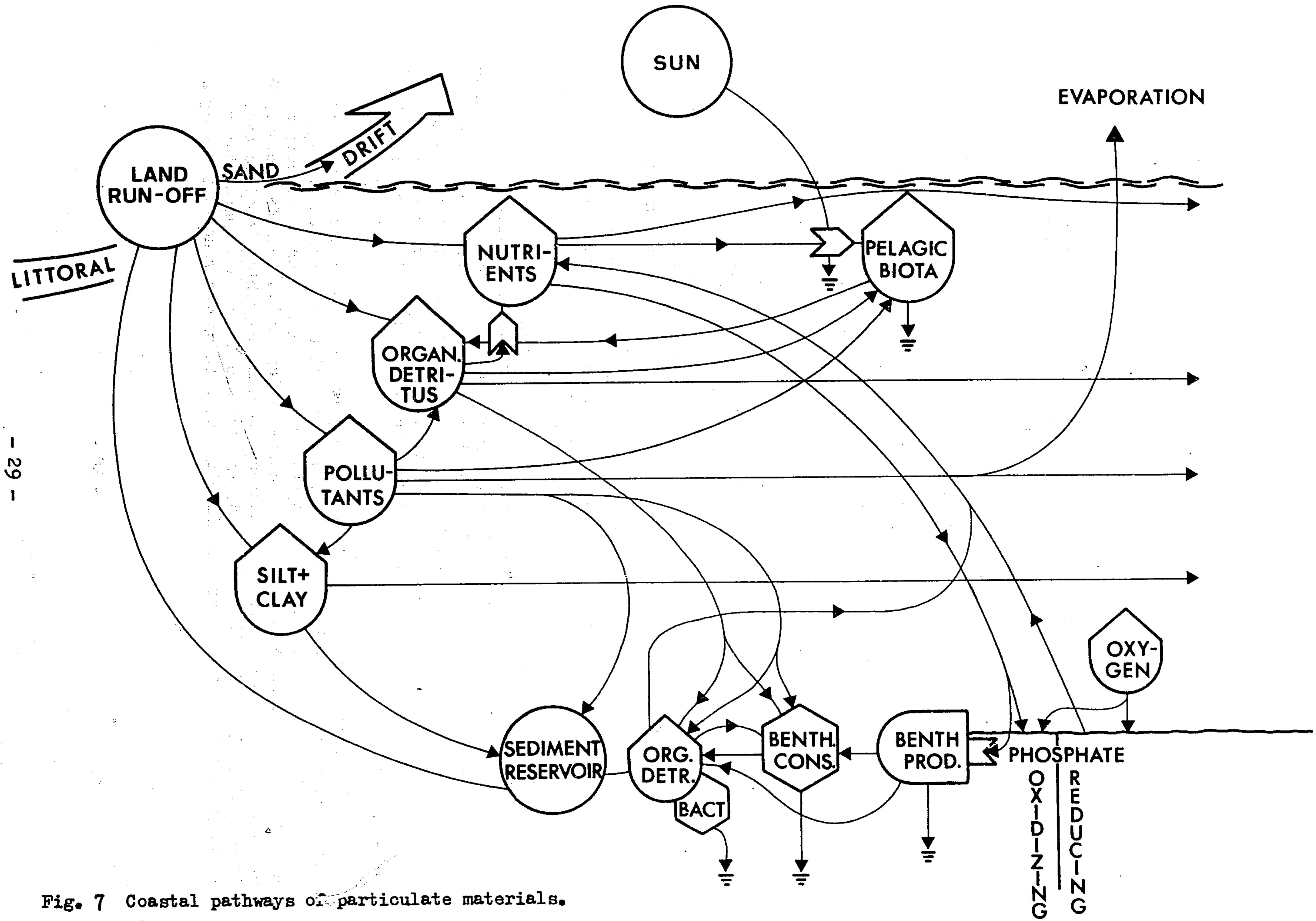


Fig. 7 Coastal pathways of particulate materials.

Along the Egyptian coast the vertical structure is 2-3 layered in the winter and 3-4 layered in the summer. The loss of structure from summer to winter results from atmospheric heat losses during the seasonal transition. The deep layer has very uniform characteristics throughout the Eastern Mediterranean ($T_p \simeq 13.6°$ and $S \simeq 38.7‰$) at depths of approximately 1,000 m and below. Direct vertical convection to this layer is not considered to occur in the Southern Levantine, making this layer only weakly coupled (through slower diffusive processes) to the upper layers in the Egyptian coastal water.

The surface layer structure in the summer consists of a warm, saline water (0-50 m) associated with the east-flowing North Atlantic water and of a warm, salinity maximum layer (100-750 m) of Levantine intermediate water. The water type during the winter is cooler, saltier, and isohaline to at least 300 m. This heavy water contributes to the water mass volume underneath the summer North Atlantic water layer, i.e. 'The Levantine Intermediate Water' (Morcos, 1972a). The water mass structure is more thoroughly discussed under the Egyptian physical review (Appendix II).

Figure 8 at the end of the section illustrates the use of energy circuit language to describe these thermohaline processes as applicable to the Egyptian coastal zone. To facilitate discussion, consider first the subsystem of incident radiation (occupying the upper left-hand corner of the figure) which takes a solar input outside the atmosphere, and provides an atmospheric output (or marine input) just under the water surface. This is a general depiction of atmospheric extinction which could be made applicable to the Egyptian coast in the computational step by inserting characteristic values. Incident radiation having both seasonal and diurnal fluctuation is subject to atmospheric reflection by clouds, absorption by gases, and scattering by particulates. By the time it reaches the sea surface it is in two forms, that coming directly (I_S) and that coming indirectly (I_D), each of which are reflected differently from the sea surface, and a small portion of that light that does finally enter the sea is back-scattered out again. The surface air temperature is determined by the incoming radiation and by the head of the air advected in by wind, the latter being particularly important during land breezes such as the sirocco winds.

Within the surface water, the extinction depends on the amount of particulates, itself a function of runoff and planktonic production (not shown). The three other interfacial processes affecting the surface temperature are shown (conduction, black body radiation, and evaporation) each having their own local dependencies. Evaporation is probably the most significant with its seasonal maximum occurring infall and winter providing, along with the interfacial loss of water vapor, the major mechanism for vertical mixing.

With a decrease in surface layer temperature or an increase in surface layer salinity, the condition of vertical convection is promoted through the associated increase in the density of the surface layer. When convection continues to the point where the surface and deeper layers have similar potential densities, then a deeper vertical exchange becomes possible, labelled overturn in Figure 8. On the other hand, an increase in surface temperatures (spring-summer) or a decrease in salinity (as with spring runoff) promotes a

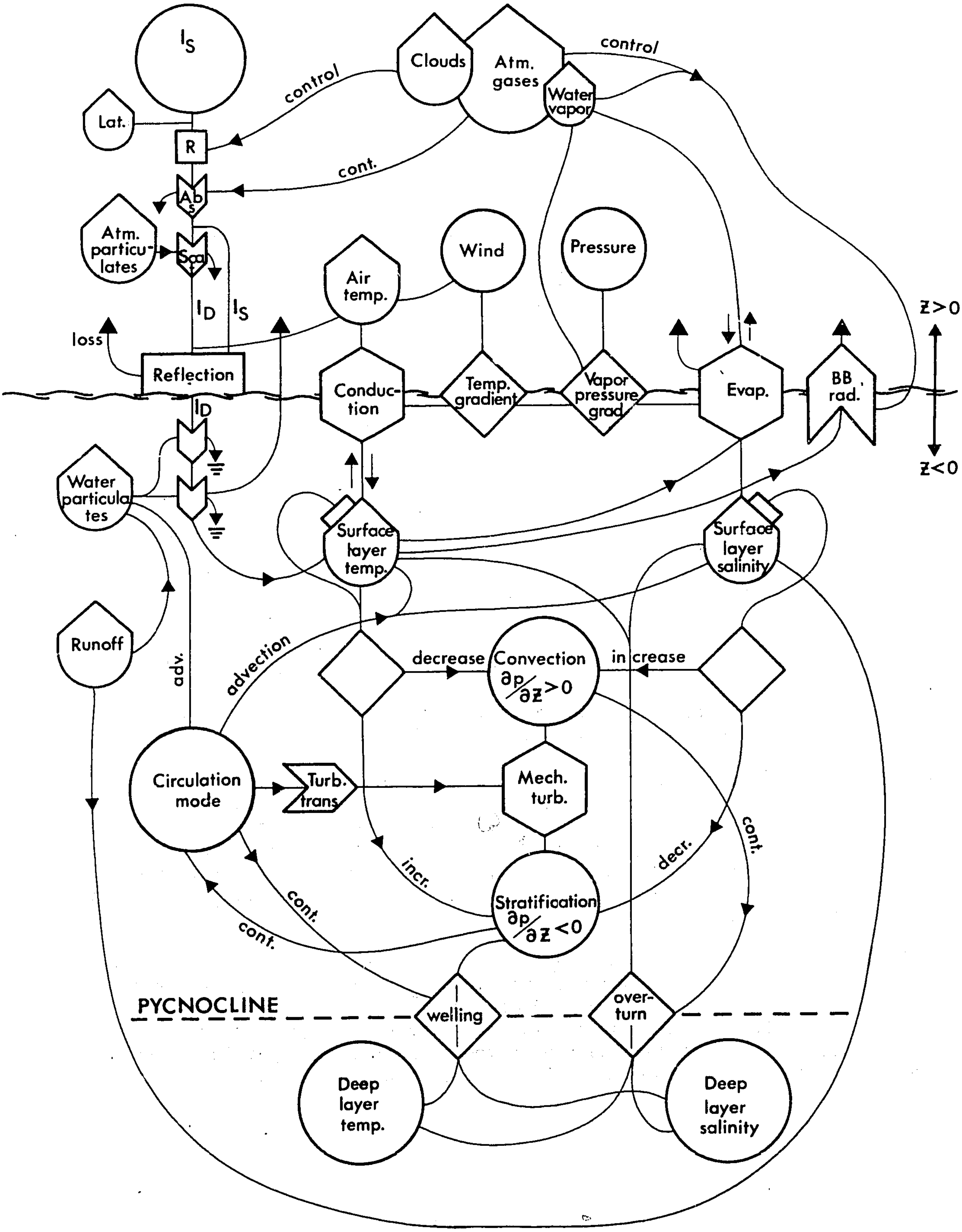


Fig. 8 Thermohaline processes applicable to the Egyptian coastal zone.

condition of stratification associated with a state of lower potential energy. In certain circulation modes the stratification is tilted, allowing the existence of the so-called conditions of boundary upwelling and downwelling which either expose deeper water to the surface layer or vice-versa.

The connecting conditions for such a subsystem are numerous and of varying degree in the strength of their couplings. The incident radiation and the circulation represent the major energy inputs and are responsible for actively driving the subsystem although, of the two, only the radiation is essential. The circulation, the intermediate water characteristics, the wind, and the pressure may be considered as a modifying energy source. The reader is reminded that within this subsystem the wind is not considered as an energy source in the sense of driving the circulation but only in terms of affecting the air-sea exchange.

The passive inputs affect the subsystem with different sensitivities and introduce varying specific and temporal dependencies. The latitude introduces no extraneous dependencies and does not sensitively affect the system with respect to the resolution to which it can be determined; whereas the river runoff introduces both spatial and temporal dependencies and affects the subsystem to a more extensive degree than is easily determinable.

F. Neritic - The pelagic subsystem

The model attempts to describe the coastal waters which, enriched by the flooding of the Nile, produced a large yield of pelagic fishes to the Egyptian fishermen, prior to the construction of the Aswan High Dam.

The High Dam is shown in the model, Fig. 9, as an outside forcing function which controls the water flow and thus the transport of nutrients and other substances in the Nile water into the Mediterranean. At low water flow, most of the organic and mineral particles, seston, will settle out long before the fresh water has reached the coast. The model also shows the presence of different "stimulating substances" in the Nile water, which by Egyptian scientists have been shown to stimulate both the primary producers and the organic consumption by higher trophic levels in the system. The lakes in the Delta area are no longer flushed with fresh water and, as a consequence, the coastal waters become less affected by pollutants, including toxic substances from industry wastes. On the other hand, fresh-water fisheries and attempts to develop aquaculture might be endangered by the increasing industrialization of the Delta region.

The major biological components within the pelagic system and their interrelationships are also shown in the model. Diatoms are the major primary producers among the phytoplankton and are controlled by solar radiation, nutrients and other stimulating substances. The organic matter produced is utilized directly by the zooplankton, composed mainly of copepods and pelagic larvae of benthic animals and pelagic fishes. The dead organic matter

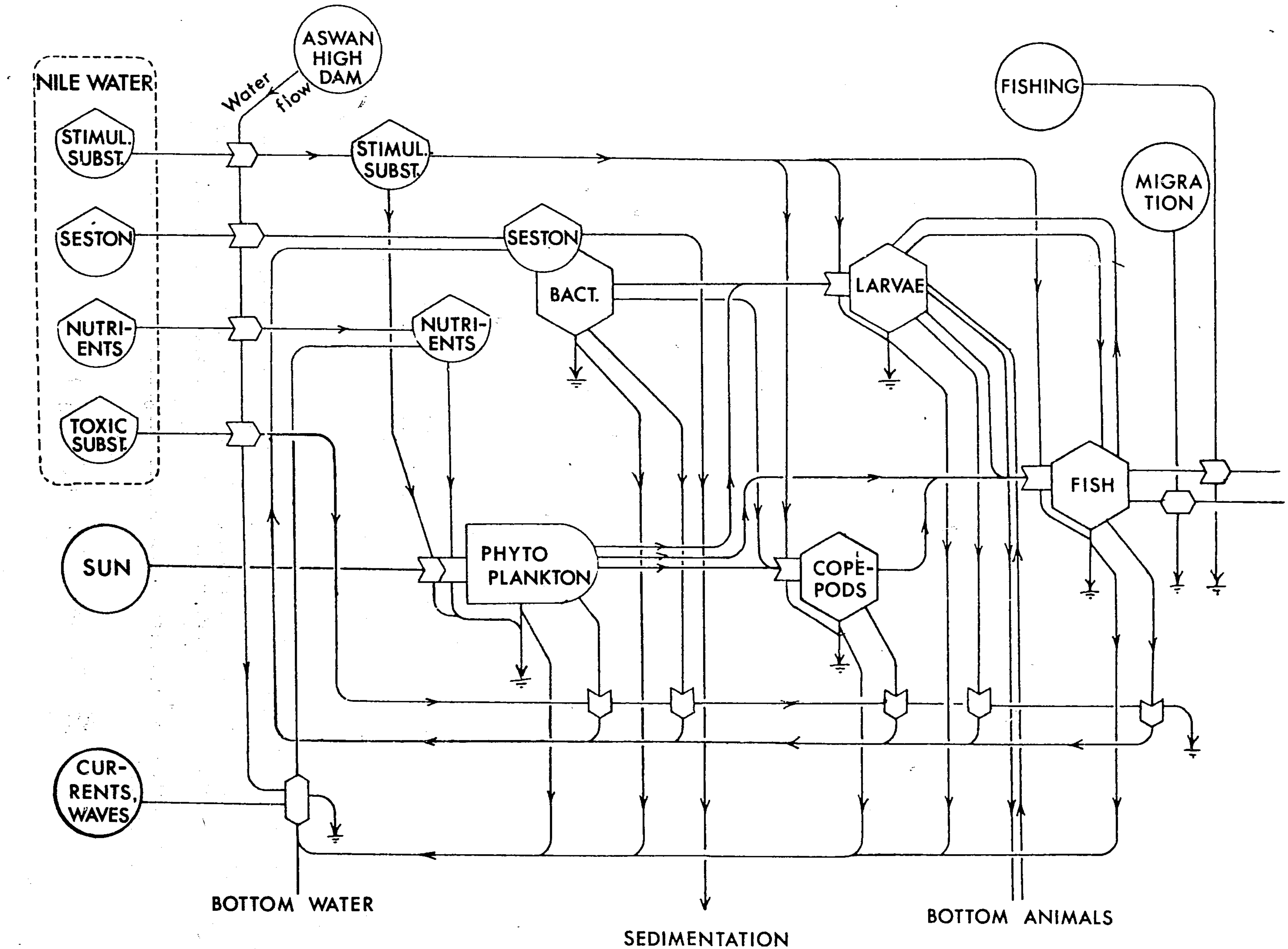


Fig. 9 The pelagic system of the Eastern Mediterranean should be studied in close connexion with Fig. 6.

included in the pool of seston, originates either from the Nile water or from dead plankton and fecal pellets. The effects of toxic substances are shown in the model to affect the mortality of the organisms by increasing the flow to the pool of seston. The organic matter is broken down by bacteria, and/or eaten by the zooplankton, or sedimented out of the system together with the inorganic particles.

The availability of inorganic nutrients in the water column is not only dependent on outside sources (Nile and bottom water) but also on the extent of nutrient regeneration within the system. The lines from the heat sink symbols show how nutrients are aided by the metabolic activity of all the organisms in the system. Coastal currents and waves determine the degree of mixing between different water layers and consequently the availability of nutrients within the trophogenic part ofthe water column.

The pelagic fishes are shown to feed on both diatoms, copepods and pelagic larvae. The migration to the coastal zone and the fishing also affects the stock of fish as well as the success of their reproduction. By following the lines between the other variables and flows in the model, many other indirect causes for a variation in the fish stock become apparent. A systems approach, as shown in this simple model, may serve as a summary of existing knowledge and as a basis for discussions as to where future research activities should be concentrated.

G. A computational example

The producer symbol of Fig. 10 can be used to illustrate how the energy circuit language is converted into mathematical expressions. Reasonable values of concentrations (g/m^2) and flows ($g/m^2/day$) have been put into the model. The data representing daily, seasonal or annual means for the system have either been collected in the field (^{14}C measurements, light and dark oxygen bottles, biomass estimates, etc.) or derived from laboratory experiments or from values extracted from the literature.

Plant biomass (Q), 100 g/m^2, is produced by photosynthesis (workgate symbol) whereby solar energy (I), 4,000 $kcal/m^2/day$, is used. A representative nutrient value (N) of 0.1 g/m^2, is shown to stimulate the primary production. The second workgate symbol represents the autocatalytic function that allows photosynthesis to be a function of plant biomass. Both workgates used here have multiplicative functions but could be replaced by a Michaelis-Menton dependence or some other expression. The energy costs for photosynthesis (heat sink symbol) are considered negligible and have not been assigned a separate value.

A figure of 10 $g/m^2/day$ is given for the gross primary production. Three flows are shown to drain the plant biomass, namely respiration (K_2Q); plant cell mortality ($K_3\,Q$); and grazing (K_4Q). These have been estimated at 30% of the gross photosynthesis, 1$g/m^2/day$ and 0.5$g/m^2/day$, respectively.

The differential equation which can be formulated for the producer module then becomes:

$$\frac{dQ}{dt} = K_1 \; INQ - K_2Q - K_3Q - K_4\,Q$$

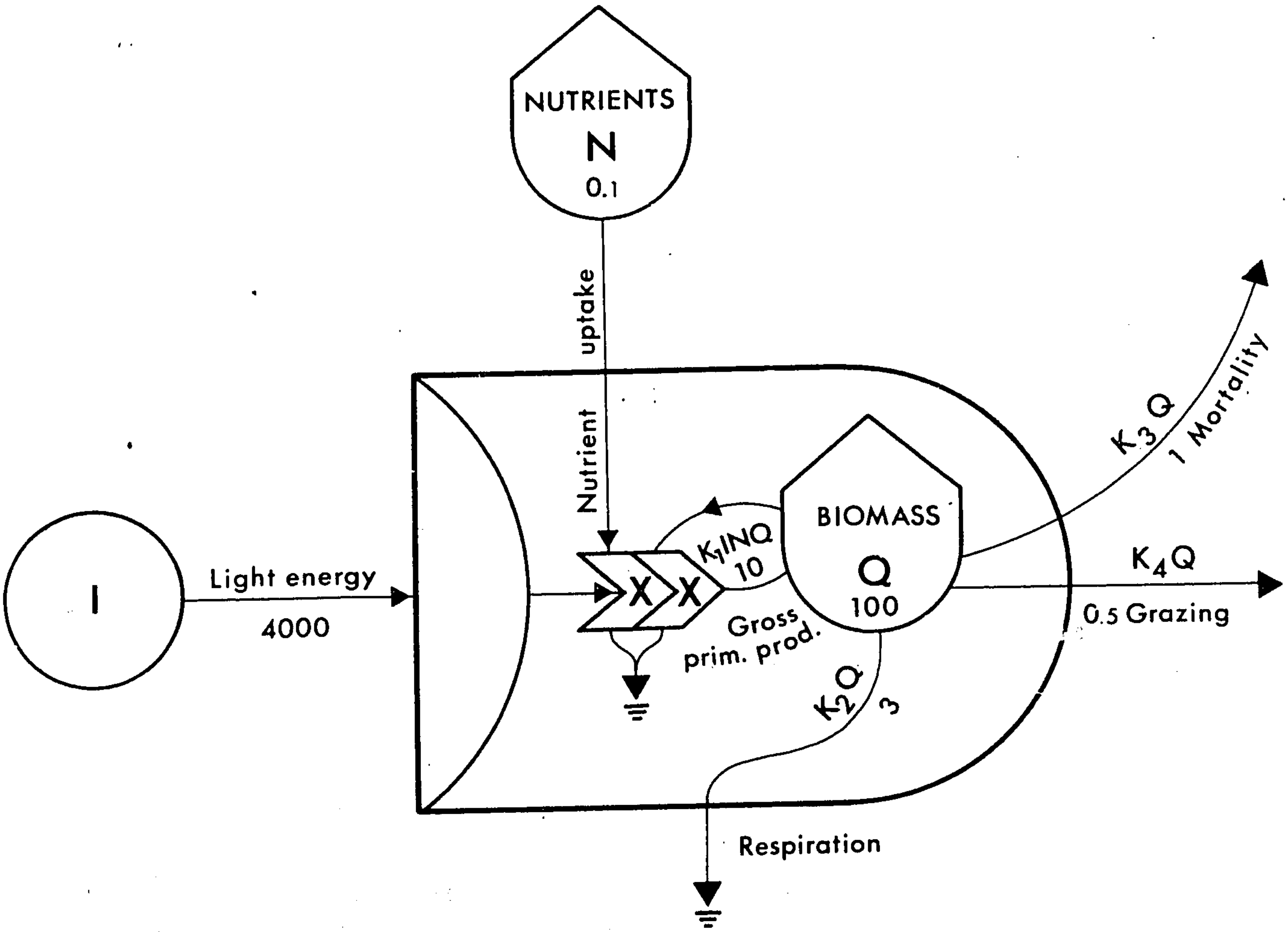


Fig. 10 A producer module showing main forcing function, storage and transfer functions with coefficients.

Applying data presented above, the following pathway coefficient can be calculated as follows:

$$\begin{cases} K_1 \times I \times N \times Q = 10 \\ K_1 = \dfrac{10}{4000 \times 0.1 \times 100} = 0.25 \times 10^{-3} \end{cases}$$

$$\begin{cases} K_2 \times Q = 3 \\ K_2 = \dfrac{3}{100} = 0.03 \end{cases}$$

$$\begin{cases} K_3 \times Q = 1 \\ K_3 = \dfrac{1}{100} = 0.01 \end{cases}$$

$$\begin{cases} K_4 Q = 0.5 \\ K_4 = \dfrac{0.5}{100} = 0.005 \end{cases}$$

Using these rates coefficients, the differential equation can be solved on a computer. In the computer solution, a time-step of one second corresponds to one day in real time.

By changing constants or variables the behaviour of the model can be explored. For example, what would happen to the plant biomass if we increase the amount of nutrients by five-fold.

IV. CONCLUSIONS

A. Applicability of modelling to the Eastern Mediterranean

From a scientific point of view, there is no reason why the Eastern Mediterranean could not become the subject of the first example of a large-scale marine ecosystem model. The sea is geographically well defined, greatly reducing the possibilities for complicated inputs. The circulation and water property flow through the Straits of Sicily and the air-sea interaction dominate the inputs. The opportunities for mass-balance calculations and the monitoring of air-sea interactions are enhanced by the relatively uniform exposure to atmospheric conditions and simplified lateral inputs.

A number of important oceanic processes occur on a smaller scale. Bottom water forms primarily in the Adriatic, and intermediate water forms in the Levantine, generating definite thermohaline circulations identifiable through water mass analysis. Strong wind-driven circulations also exist on seasonal time scales, for example the Meltemi (northerlies) over the Aegean, or upwelling along the eastern shore of the Levantine.

The basin is sufficiently isolated geographically to have fostered endemic species. Species migration through the area is relatively easy to monitor and is of vital importance to the peripheral countries. The waters as a whole are among the most oligotrophic in the world, causing greater environmental sensitivities throughout the food chain.

The need to determine these sensitivities is being dramatically demonstrated as observations indicate that adjustments to the Suez Canal and the Aswan High Dam are still occurring. These two events have been well enough documented historically to serve as excellent modelling problems that would provide the opportunity for real time confirmation, as the repercussions of these events continue. Local coastal eutrophication caused by increased urban waste disposal likewise presents attractive modelling opportunities. The effects of these discharges are very well defined due to the oligotrophic background, again affording excellent possibilities for real time confirmation. As these smaller scale local effects increase they must be incorporated as inputs or interactions into the larger Eastern Mediterranean models.

We feel that this sea provides a unique combination of need and feasibility for a concerted international effort to address its marine problems through the avenue of marine ecosystem modelling.

B. Workshop recommendations

Requests for collaboration and mutual assistance were pervasive during the many discussions. The need for an international organization to provide the impetus for any future projects was recognized as essential since such undertakings were clearly beyond the scope of individual participating countries. In many respects the need was for coordination and partial support. The following recommendations are meant to serve as a directional framework to the type of activities agreed upon as necessary, not only to the pursuance of healthy research in the region, but also to continue the modelling efforts initiated by the workshop.

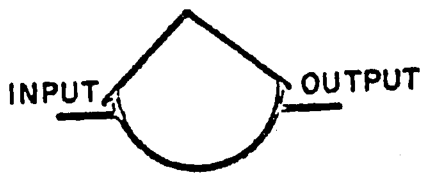
1. Within the near future, a second similar modelling workshop should be held, but focusing on another Eastern Mediterranean region, such as the Aegaen or Adriatic Seas.

2. A symposium on the results of current research in the Eastern Mediterranean should be planned for some future date.

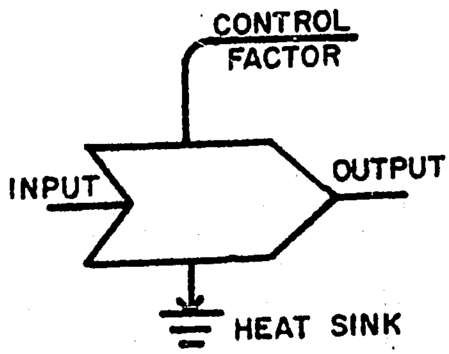
3. Modelling methodology, experiment design, and standardization of data collection were recognized as areas needing specific attention to expedite solid international interfacing of research efforts.

4. The recommendations of the proposed action plan for the Eastern Mediterranean (Appendix V) were specifically endorsed.

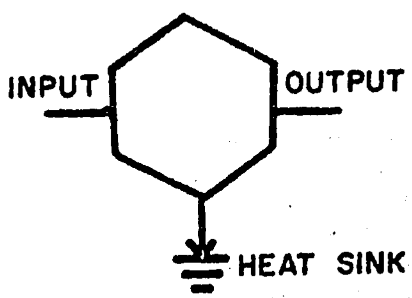
THE ENERGY CIRCUIT LANGUAGE - THE SYMBOLS



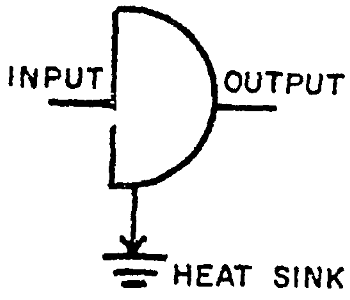
a. PASSIVE STORAGE symbol showing location in a system for passive storage such as moving potatoes into a grocery store or fuel into a tank. No new potential energy is generated and some work must be done in the process of moving the potential energy in and out of the storage by some other unit.



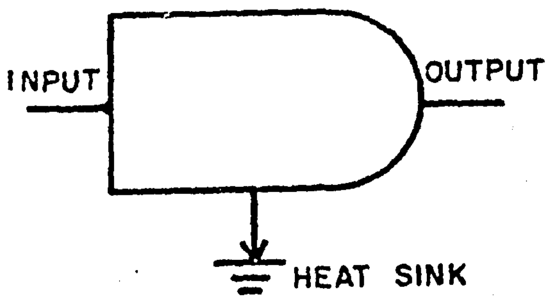
b. WORKGATE module at which a flow of energy (control factor) make possible another flow of energy (input-output). This action may be simple as a person turning a valve, or it may be the interaction of a limiting fertilizer in photosynthesis.



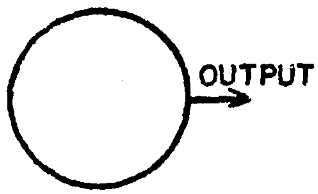
c. SELF-MAINTAINING CONSUMER POPULATION symbol represents a combination of "active storage" and a "multiplier" by which potential energy stored in one or more sites in a subsystem is fed back to do work on the successful processing and work of that unit.



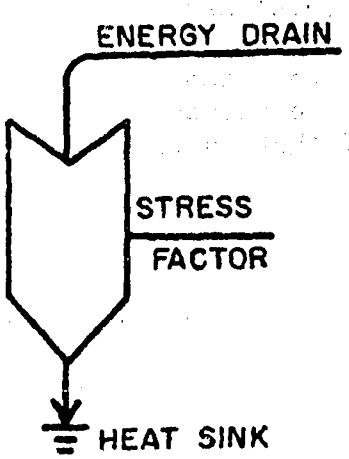
d. PURE ENERGY RECEPTOR symbol represents the reception of pure wave energy such as sound, light, and water waves. In this module energy interacts with some cycling material producing an energy-activated state, which then returns to its deactivated state passing energy on to the next step in a chain of processes. The kinetics of this module was first discovered in a reaction of an enzyme with its substrate and is called a Michaelis-Menton reaction.



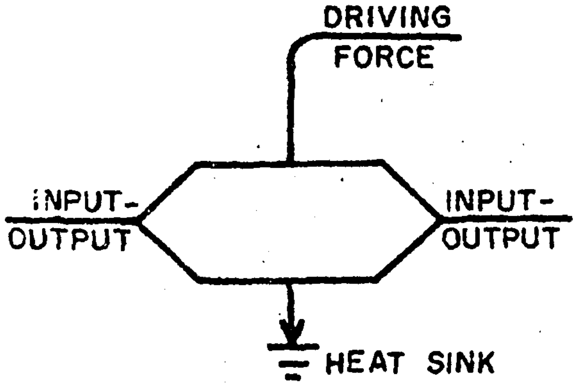
e. PLANT POPULATION symbol is a combination of a "consumer unit" and a "pure energy receptor." Energy captured by a cycling receptor unit is passed to self-maintaining unit that also keeps the cycling receptor machinery working, and returns necessary materials to it. The green plant is an example.



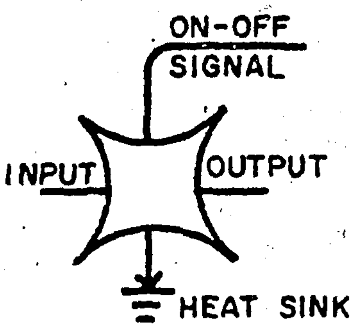
f. ENERGY SOURCE symbol represents a source of energy such as the sun, fossil fuel, or the water from a reservoir. A full description of this source would require supplementary description indicating if the source were constant force, constant flux, or programmed in a particular sequence with, for example, a square wave or sine wave.



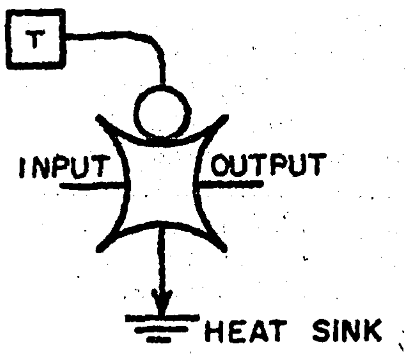
g. STRESS SYMBOL defines the drain of calories of potential energy flow. When a system is stressed, the potential energy that was available to do work is lost. The curve for a stress factor follows the rectangular hyperbola of a workgate but in opposite direction. The stress symbol is then an inverted workgate with energy from the system being drained into a heat sink by an environmental factor (the stress) shown on the opposite side of the workgate.



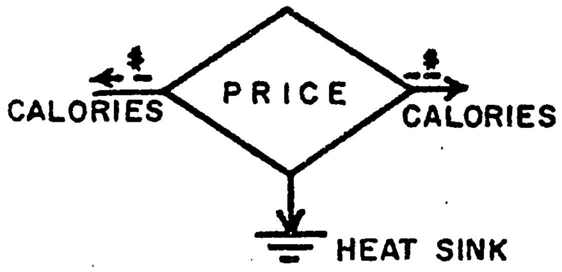
h. TWO-WAY GATE OR FORCED DIFFUSION MODULE represents the movement of materials in two directions as in the vertical movement of minerals and plankton in the sea. The movement is in proportion to a concentration gradient or a causal force shown operating the gate. The heat sink shows the action to follow the second law of thermodynamics.



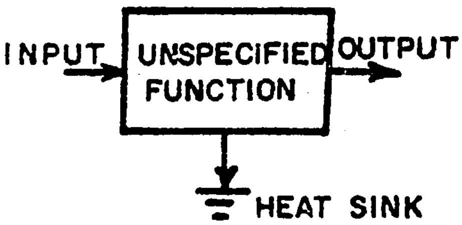
i. SWITCH is used for flows, which have only on and off states controlling other flows by switching actions. There are many possible switching actions as classified in discussions of digital logic. Some are simple on and off; others are on when two or more energy flows are simultaneously on; some are on when connecting energy flows are off, and so forth. Many actions of complex organisms and man are on and off switching actions such as voting, reproduction, and starting the car.



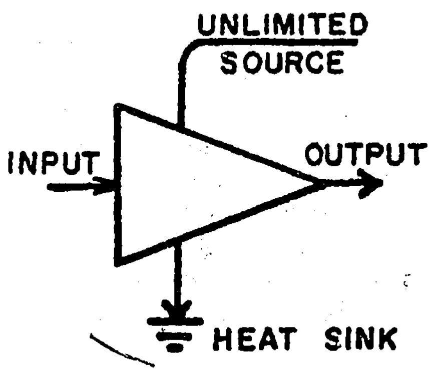
j. LOGIC SWITCH follows the same kinetics of the ON-OFF switch described above. In order for the logic switch to be operative, however, a certain valve in the module controlling the ON-OFF signal must have been attained. When the threshold "T" is high, flow is off. For example, when simulating the effects of water level on a biological process, a threshold value, representative of a critical level, is used to turn the process ON or OFF. This symbol is useful in working with analog computers with logic boards.



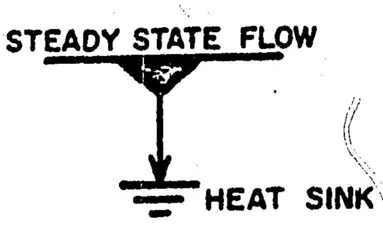
k. ECONOMIC TRANSACTOR symbol is used for systems that have money cycles as well as energy flows. Money flows in the opposite direction to the flow of energy and the concept of price which operates among human bargains adjusts one flow to be in proportion to the other. Thus a man purchasing groceries at a store receives groceries in one direction while paying money in the opposite direction. The heat losses of these transactions are small since the work involved is small. If there are complex structures regulating the transactions the costs of the coupling may be great.



l. BOX symbol is used when an unspecified action is being represented, or when the function is unknown or unimportant to the point being made. If the function is known, but no specific symbol is available, a box may be used with the function written inside.



m. CONSTANT GAIN AMPLIFIER. In this module the amount of energy supplied from the upper flow is that necessary to increase the force expressed by the system by a constant factor, which is called the gain. For example, a species reproducing with 10 offspring has a gain of 10 so long as the energy supplies are more than adequate to maintain this rate of increase.



n. This symbol is used to represent the energy losses associated with friction and backforces along pathways of energy flow.

REVIEW OF EGYPTIAN RESEARCH

The Workshop focused its attention on the Egyptian Coastal zone as the example of an Eastern Mediterranean subsystem. In order to facilitate this, Egyptian scientists submitted to the Workshop extensive background material in each of their areas of interest. This component information is summarized in the following sections:

A. PRIMARY PRODUCTION, PHYTOPLANKTON AND ZOOPLANKTON STUDIES IN EGYPTIAN MEDITERRANEAN WATERS - PHYTOPLANKTON

Investigations of the phytoplankton of Egyptian waters started in 1956, and since then have been carried on at more or less regular intervals by different investigators. The region around Alexandria was more regularly studied, but observations also have been conducted in the Rosetta, Damietta and Port-Said regions. The results include qualitative studies on the species composition, on their relative importance, and on their bio-geographic affinities. The accompanying quantitative data were obtained by sedimentation and counting methods at monthly intervals. Such data are available for Alexandria for the years 1957 (El-Maghraby and Halim, 196) and 1968-70 (Sultan, 1975). During the latter year, simultaneous measurements of Carbon-14, assimilation, chlorophyll content and relative light extinction were also made. The plankton production and composition in the Rosetta estuary and its peculiar conditions were investigated in 1973 (Halim _et al._, 1974). The area around the Damietta outlet of the Nile was studied for three successive years, 1956, 1957 and 1959, but the observations were restricted to the period of the Nile bloom season, July-September (Halim, 1960b). The standing crop of diatoms and their species were followed during a year-cycle at Port-Said harbour in 1970. Since at that time the harbour was free of ship wastes, its waters were assumed to represent unpolluted inshore Mediterranean conditions (Dorgham, 1974).

Apart from these localized observations, extensive surveys covering the continental shelf from 29°E to 32°-33°E were made by the Soviet R/V ICHTHYOLOG and its participating Egyptian scientists. The cruise of October 1964 yielded observations on the plankton and the hydrographic conditions during the last normal Nile flood (Halim _et al._, 1967). Four seasonal cruises were made in 1966, just after the construction of the Aswan High Dam.

The information obtained can be summarized as follows : the species composition in the different localities, their monthly succession and their relative numerical importance were recorded. More specifically, systematic contributions involving the description of new species were given by Salah and Tamas (1969, 1970), for diatoms and by Halim (1960 b) and Hassan (1973) for dinoflagellates. Check-lists were compiled by Salah (1971) and Dowidar (1974 c). The blooms are always due to the same diatom species for all Mediterranean localities, mainly, _Thalassionema nitzshioides_, _Chaetoceros curvesitus_, _C. Socialis_, _Cerataulina bergoni_, _Leptocylindrus danicus_. All the recorded diatom species have proved to be Mediterranean-Atlantic, except for _Hemiaulus membranaceus_ and _Biddulphia tuomei_, occuring in Port-Said and suspected to be Indo-Pacific in origin.

The case is different for dinoflagellates. A number of species of a peculiar biogeographic affinity occur sometimes in abundance. They are either Indo-Pacific immigrants or autochthonous forms. Of the former, *Pyrodinium schilleri* is common in Port-Said and *Peridinium nipponicum* in Alexandrian plankton (Halim, 1963 and 1965; Hassan, 1973). *Ceratium egyptiacum*, a species indigenous to the Suez Gulf and Suez Canal, is now spreading to the Mediterranean (Dowidar, 1971). *Exuviaella cordata*, abundant in our waters as well as in the Aral, Caspian and Black Seas, has not been found in the West Mediterranean, or elsewhere. *Alexandrium minutum* is a typical example of an autochthonous species, found only in the Alexandria region (Halim, 1960). Discolouration of the East Harbour waters every summer is due to the proliferation (up to 20 millions cells/l) of this small species.

A major change has taken place since 1965, affecting both the magnitude of the standing stock and the periodicity of the blooms. The quantitative cycle was typical of this area, reflecting the tremendous fertilizing effect of the Nile outflow by the end of summer. It presented two peaks, a minor one in winter or early spring and an outstanding September peak, usually in the ratio of 1:50 to 1:100. After 1965 a reversal took place, the autumn bloom being reduced to 1:7 of the winter bloom. The phytoplankton cycle, now governed by intrinsically marine factors, is analogous in the bimodal shape of its annual curve and in the relative magnitude of its two blooms to all phytoplankton cycles observed in Mediterranean-North Atlantic localities that are free from influence of terrestrial runoff.

Measurements of primary production were made in the open sea in 1969-70, along a section (Stations I, II and III) extending from the eutrophied part of the East Harbour of Alexandria to the shelf break (Sultan, 1975). Chlorophyll *a*, at the nearshore station, was comparable in range (0.2-2.7 µg/l) to that found in the North West Mediterranean (Nival *et al.*, 1972) and near Malta (C. Agius, priv. comm.), but higher than near Greece (Hopkins *et al.*, 1976). A seaward decrease is observed (0.1-0.6 µg/l at St. III), while the depth of the photic layer is increasing. The level of 1% relative light intensity increases in depth from 70.6 m (St. I), to 80 m at the limit of the shelf. The Carbon-14 results for the open sea stations, obtained from incuvated samples at optimum light intensity, were relatively high compared to other Mediterranean observations (Sournia, 1973). They were respectively 313, 219 and 175 gC/m^2/year. Peaks of about 2 gC/m^2/day are reported from a divergence zone in the North-west Mediterranean (Minas *et al.*, in Sournia, 1973). *In situ* measurements in the East Harbour yielded 584 gC/m^2/year.

Zooplankton

Several semi-quantitative surveys of the zooplankton populations of Alexandrian waters have been carried out in the last decade. They include either temporal observations at a fixed station (Guerguess, 1970, for 1965) or both temporal and spatial observations. Dowidar and El-Maghraby (1970a and 1971) reported on the neritic zooplankton from Abu Qir and the east to Agamy west of Alexandria, in 1961-62, with particular reference to the *Copepoda*. Abu El-Ez (1975) worked the zooplankton from Rosetta in the east to the Arab Gulf west of Alexandria, in 1969-70, with particular reference to the *Appendicularia*. The ICHTHYOLOG survey of October 1964, during the last normal Nile flood, covered a more extensive area, from the Arabs Gulf to Pelisium Bay, east of Port-Said (Halim *et al.*, 1967), but it was restricted in duration to one month.

All results are expressed as numbers of organisms per cubic metre as obtained from counts of vertical hauls. Taken in this manner the results are at least comparative within each set of observations. A more adequate approach for the assessment of the secondary production is still needed.

The zooplankton groups which received more attention than others, namely the Copepoda, the Chaetognatha and the Appendicularia are discussed in more detail below:

Copepoda. Since 1964 several contributions to the study of the plankton copepods of the South-east Levantine Sea have appeared : El-Maghraby and Halim (1964), El-Maghraby (1964, 1965). El-Maghraby and Dowidar (1970), Dowidar and El-Maghraby (1971 and 1973a). The population was found to be fairly diversified, although the number of species, 132, is lower than in the Adriatic (200 species) or in the Gulf of Naples (157 species). Some ten smaller species, such as Paracalanus parvus, Oithona nana, Calocalanus pavo, are dominant all the year round. All of the recorded species are Mediterranean-North Atlantic. Three of the bathypelagic species seem to be new : Megacalanus longicornis, Gaidius tenuicornis and Euchirella maxima. On the other hand, some species are given as possible immigrants from the Red Sea, Paracalanus aculeatus and Calocalanus pavo; and other species, Calanus tenuispinus, Isias clavipes, Acartia danae, Centropages violaceus and Pontellina plumata, as indicators of the Atlantic current. The latter two species, however, are common and widespread in the Red Sea, including the Gulf of Suez (Halim, 1969b).

Chaetognatha. Seven Sagitta species are now known to occur in the Egyptian Mediterranean waters. They are by order of abundance : Sagitta friderici, S. serratodentata, S. enflata, S. minima, S. bipunctata, S. Hexaptera, S. neglecta. The morphometric characters and the biology of about 8000 specimens belonging to the common species have been studied. S. Friderici, believed until then to be an allochthonous species to the Mediterranean, proved to be a permanent and dominant component of the South-east Levantine plankton (77% of all Sagitta sp.). This euryhaline surface species breeds all year around, except in mid-summer. The morphometric characters of the larva and its development, only little known, were also studied.

Appendicularia. Five appendicularian species were found to be dominant : Appendicularia sicula, Oikopleura longicauda, O. dioica, O. parva and Fritillaria borealis. Appendicularia sicula, a rare species in the Western Mediterranean, proved to be dominant in Egyptian waters (50% of all Appendicularians). Some correlation could be found between the peaks of abundance of these filter feeders with phytoplankton productivity.

B. LITTORAL MACROBENTHIC COMMUNITIES

Until now relatively little attention has been given to the benthic communities of littoral Egyptian waters. The available information is entirely qualitative, consisting mainly of species records from one area or another.

Fairly good records are available, although by no means recent, of the species composition of the littoral macrobenthic communities of two areas : the Port-Said Harbour, and the Alexandria region. The former was faunistically surveyed during the Cambridge Expedition to the Suez Canal in 1924 (Fox, 1926). The area represents, on the whole, the conditions of a Mediterranean harbour in which the number of macrobenthic species is relatively small and where several Red Sea immigrants through the Suez Canal are well established and even surpass the Mediterranean forms.

Macrobenthos. A detailed qualitative survey of the macrobenthic communities in the Alexandria region and Abu Qir bay was carried out by Steuer (1935) in the summer and autumn of 1934. Samples were dredged from 147 stations scattered in the littoral region from the Rosetta Nile mouth to the area off Alexandria (between 29°40 E and 30°20 E) from depths rarely extending beyond the 100 fathom line. The semi-enclosed Western Harbour of Alexandria received considerable attention; for example, more than one third of the dredging effort was confined to this basin. In a preliminary report, Steuer (1935) described the area of collection in regard to its topography, sedimentation, and the vegetation associated with the different biotopes. He also differentiated the biotic communities surveyed, defining the characteristic invertebrate forms, and comparing them with the littoral communities of other Mediterranean regions. Steuer also described the fauna of the two coastal lakes (Lakes Maryut and Edku) which extend along the coast of Alexandria and Abu Qir.

The various invertebrate groups sorted from Steuer's collection were identified to their species by various taxonomists. In their reports published under the general heading of the "Fishery Ground Near Alexandria", they listed the species indentified, described many of them, and charted their locations in the area surveyed. They also gave their geographic distribution and referred to the Red Sea immigrant species encountered in their samples.

The total number of the recorded species from the main invertebrate groups compiled from these reports, are given in the following table :

Invertebrate group	Author	Total No. of species	Medit.-Atlantic	Red Sea
Sponges	Burton (1936)	45	42	3
Hydroidea	Billard (1936)	13	11	2
Polychaeta	Fauvel (1937)	122	121	1
Tanaidacea and Isopoda	Larwood (1940)	29	26	3
Amphipoda	Schellenberg (1936)	43	41	2
Cirripedia	Broch (1935)	5	5	-
Decapoda	Balss (1936)	64	49	9
Bryozoa	O'Donoghue and Watteville (1939)	62	62	-
Amphineura	Steuer (1939)	3		
Gastropoda	Steuer (1939)	108		
Lamellibranchiata	Steuer (1939)	77		
Echinodermata	Mortensen and Steuer (1937)	33	24	1
Tunicata	Harrant (1939)	21	20	1

The relatively few number of species recorded in Steuer's collection, in comparison to other Mediterranean areas, has been noted by several authors. Some suggested that the limited period of collection (6 months) and the sparse population of some of the species did not allow a complete record of all in the area. This conclusion appears to be confirmed by a recent investigation of the bivalves and gastropods in Abu Qir Bay by Hassan (1974). Monthly collections were carried out from several inshore and offshore stations in the Bay for one complete year. Hassan recorded 118 species, including 69 bivalves and 49 gastropods. Of these, 108 were obtained from the shallower zone of the Bay, as opposed to 35 recorded by Steuer. Hassan (1974) described and catalogued the species recorded and gave a detailed semi-quantitative account of their abundance and distribution as a function of the bottom type and the depth.

Epifauna. The epifauna developing on submerged surfaces (fouling communities) in the Eastern Harbour of Alexandria has recently received considerable attention. Megally (1970) described the fouling communities on ship hulls anchored in the harbour. Using experimental panels, he followed qualitatively and quantitatively both the seasonal and biological succession of the foulers. He also studied the effects of some factors, such as the substratum nature and texture, surface angle, depth of immersion, shade and temperature, on the attachment and density of the fouling growths.

El-Nasry(1973) carried out a qualitative and quantitative study on the Amphipods, Isopods, Tanaidacea, and Copepods associated with fouling growths in the Eastern Harbour. He identified several species and described their external structures. He also followed the quantitative seasonal variation of their populations and the succession of their broods, and described the optimal conditions for breeding and abundance.

Ghobashy and Selim (1976b,c,d) studied the settlement behaviour and growth of the tube worms Hydroides norvegica and Spirobis corrugatus on experimental panels in the Eastern Harbour. Ghobashy (1976a) made further studies on the seasonal variations and settlement behaviour of the fouling organisms and investigated also the growth rates of four barnacle species in the Eastern Harbour.

Macro-algae. Floristic and floristic-ecological surveys of the algal vegetation around Alexandria started by Nasr (1940a and b). The growth, life history and distribution of Ectocarpus siliculosus in lake Edku have been investigated by Nasr and Mohsen (1961a and b). Physio-ecological studies have been carried out on several species, in particular Cosmarium botrytis (Mohsen, 1966a and b), Pterocladia capillacea (Nasr, Mohsen and Bekheet, 1966b), Ulva fasciata (Nasr, Mohsen and Metwalli, 1972a and b), Ulva, Dictyota. Agar production from local agarophytes has also received some attention (Mohamed and Halim, 1952, Samaan, 1960, Nasr, Mohsen and Bekheet, 1966).

Concluding remarks. It is evident from this review that the work done on the benthic communities of the littoral Egyptian Mediterranean is far from complete. Very wide areas are still unexplored and the quantitative aspect of the subject is completely lacking and must take first priority in any future studies.

The immigration of the Red Sea species must also be closely integrated into any future study. There is evidence that other Red Sea immigrants are present in the area. For example, Steinitz (1967) records some Red Sea species along the southeastern Mediterranean coast. Moreover, the drastic reduction of the Nile water input to the area and the accompanied drop in its fertility have exerted great ecological stress on the populations in the Mediterranean waters.

C. CHEMICAL STUDIES IN THE EGYPTIAN MEDITERRANEAN WATERS

The available literature dealing with the chemistry of the southeastern Mediterranean waters is very scanty. Furthermore, nearly all of the research done in this field was made in conjunction with regional hydrographic surveys.

Between 1914 and 1959 only 47 hydrographic stations had been taken in the southeastern Mediterranean, and only a few included data on nutrients. These were the DANA (1928-1930); the Swedish Deep Sea Expedition on R/V ALBATROSS (1947-48); the ATLANTIS (1948, 1958, 1962); the CALYPSO (1956) and the AKADEMIC S. VAVILOV (1959). During the active years of the International Indian Ocean Expedition (1960-1965), a number of research vessels occupied a few stations in the eastern Mediterranean on their way to or from the Indian Ocean through the Suez Canal (ATLANTIS II, METEOR, CHAIN, AYTODOR, and DISCOVERY).

Important and large-scale contributions to our knowledge of the hydrography and chemistry of the southeastern Mediterranean was made by the Soviet-Egyptian Expeditions on board R/V ICHTHYOLOG in 1964, 1966 and 1971-72. In October 1964 the ICHTHYOLOG surveyed the Egyptian Mediterranean waters from the Gulf of Pelusium in the east to the Arabs Gulf in the West occupying 20 stations, and covering the continental shelf. The results of this expedition, made during the last normal flood season of the Nile, were reported by Halim et al., (1967). They include data on temperature, salinity, dissolved oxygen, phosphate and silicate as well as plankton. The maximum and minimum nutrient concentrations were as follows:

	Arabs Gulf	Off Nile Delta	Gulf of Pelusium
Phosphate P-µgat/l	0.08 - 0.1	0.12 - 0.27	0.07 - 0.09
Silicate Si-µgat/l	not recorded	3.7 - 10.4	7.8 - 14.1

In 1966, the ICHTHYOLOG made four seasonal cruises in the area between El Arish to the east and the Arabs Gulf to the West. During each of the four seasonal cruises, six perpendicular sections to the coast were sampled; each comprising five stations, covering depths from 10 m to about 1000.

The data obtained represent the first survey of the Egyptian Mediterranean waters after the new Aswan Dam became functional in 1965. They cover the hydrographic conditions (Moustafa-Hassan, 1969, Morcos and Moustafa Hassan, 1976), dissolved oxygen, phosphate and oxidizable organic matter (Emara, 1969; Emara et al., 1972). In 1971-72, a similar survey was carried out by the third ICHTHYOLOG expedition, covering the area between Damietta and El-Salloum (Al-Kholy and El-Wakeel, 1975).

Phosphate, nitrite, nitrate, ammonia and silicate, in addition to salinity, temperature and dissolved oxygen were measured during seven cruises (September 1969 to August 1970) along a section extending 30 miles to the north of Alexandria (El Rayis, 1973, Morcos and El-Rayis, 1973). Spring and summer were very poor in nutrients with no significant increase down to 500 m, but the September data showed an increase in nutrients at all levels.

A nucleus of high content in phosphate (0.55 µgat/l), nitrate (6.0 µgat/l), nitrite (0.30 µgat/l) and silicate (13 µgat/l) appears at 300 m.

In addition to this coastal research, the northern Delta lakes have been the site of regular work by several investigators. The chemistry of Lakes Manzalah, Borollos, Edku and Maryut is now fairly well known. These lakes receive variable amounts of drainage water from cultivated lands (Table 1).

Table 1 : Amount of land drainage received by the northern Delta lakes and the concentration of nutrient salts in their waters in µgat/l

Lake	Area sq. Km	Annual drainage 10^6 m^3	PO_4 - P range	SiO_2 - Si range	NO_3 - N range	NO_2 - N range
Manzalah	1260	4600	0 - 4.8	75-765	0-274	0-20
Borollus	504	2785	0 - 1,74	135-399	0-240	0-73
Edku	130	1960	0.01-2.88	11-287	0.02.-21	0.1-4
Maryut	63		0 - 3.5	0-300	0-25	0-28

With the exception of Lake Maryut, all these lakes are connected to the Mediterranean Sea by small openings (boughaz) which allow free exchange of water between the sea and the lake. Through these connections variable amounts of brackish water rich in nutrients are discharged into the sea. The magnitude of this brackish water outflow and its fertilizing effect on the adjacent Mediterranean water remains to be studied. Further, about 3500 million m^3 of Nile water is discharged annually to the Mediterranean Sea at the Rosetta outlet through Edfina barrage. Over 90% of this volume is discharged in winter (December - February). In addition, about 2000 million m^3 are discharged into the Bay of Mex by the Mex Pumping Station and about 700 million m^3 are pumped out in Abu Qir Bay by El Tabia Pumping Station. Besides the brackish water discharged through these three lake-sea connections, about 5500 million m^3 of fresh and brackish water is discharged directly into the sea. This amount represents only about 12% of the volume annually discharged into the sea during the flood season prior to the Aswan High Dam. This brackish water is naturally rich in nutrients and contains both agricultural and industrial wastes. The resulting effects on the fertility of the coastal waters still remains to be investigated.

Future research must address itself to determining the level of eutrophication needed to sustain a required productivity within the coastal waters off the Nile Delta. This research would accompany the management of the release of Nile water and the monitoring of its effects.

D. PHYSICAL OCEANOGRAPHY - CIRCULATION AND WATER MASSES ALONG THE EGYPTIAN COAST

The earliest hydrographic observations in the Eastern Mediterranean Sea date back to 1889 with the Russian ship "VITYAZ". During the last 30 years, cruises have been carried out along the Mediterranean coast of Egypt by research vessels from different nations. Their main purpose was to make hydrographic and biological observations. In 1948 six hydrographic stations were taken by the ATLANTIS and during 1955-1956 two by the CALYPSO between the Egyptian coast, Cyprus and Crete, respectively. In March 1959, 19 stations were taken seaward of the Nile Delta and the West coast of Egypt by the Japanese ship SHOYO MARU (Gorgy and Shaheen, 1964; Morcos, 1967, 1972) and nine during the summer by the Russian ship AKADEMIC S. VAVILOV. The Yugoslavian ships, OVCICA and GOLOBICA took 35 oceanographic stations between 1959 and 1961 (Gorgy, 1966). According to an agreement between the Institute of Oceanography and Fisheries in Egypt and the Soviet Government, the Russian ship ICHTHYOLOG carried out a joint programme along the Egyptian coast taking 16 stations during October 1964 (Halim et al., 1967), 205 during the four seasons of 1966 (Moustafa Hassan, 1969; Morcos and Moustafa Hassan, 1976) and 36 during the four seasons of 1971 (Al-Kholy et al., 1975). Several cruises were made along the coast over the continental shelf by ships of the Egyptian Navy between 1963 and 1968.

Direct current measurements over the continental shelf off the Nile Delta and lake inlets are scarce. At the Rosetta mouth, currents were measured by the Suez Canal Authority between July 1969 and June 1970 (Hilaly, 1971a). Along the coast near Damietta, measurements were taken from January to June 1969 at four locations (Kadib, 1971). Currents were measured at both of these areas with a submerged float released from various locations; velocity was recorded twice a day (morning and afternoon). Also, near Damietta current observations were carried out for 18 months, starting in December 1964 (Mobarek et al., 1966), with two techniques. The first employed a paddle-wheel current meter at four locations seaward of the breaker zone; the second used a float deployed at four points along the 10 km stretch of Ras al-Barr shore-line. From September 1969 to June 1970, currents were measured by float drogues deployed at five localities on each side of the Borollus inlet (Hilaly, 1971b). Over the continental shelf seaward of the Nile Delta, an Ekman current meter was used at five stations between October 1959 and October 1960. The current meter was operated at 4 m below the surface. During 1966, an Ekman current meter was used to measure surface and subsurface currents at 23 ICHTHYOLOG stations between Port-Said and Abu Qir Bay (Moustafa Hassan, 1969).

The effect of the Nile flood along the Egyptian Coast, before the construction of the Aswan High Dam in 1964, was noticeable in autumn for a few kilometres from the coast to depths of 10-20 m (Halim et al., 1967). The continental shelf water can be treated as a 3-layer system in summer based on its temperature and salinity properties (Morcos, 1972a and Gerges, 1974). A warm surface layer 50 m thick with high salinity overlays a subsurface layer of low salinity and a deeper layer with high salinity (Gorgy and Shaheen, 1964; Morcos, 1967, 1972a; Sharaf El Din, 1972a; Morcos and El-Rayis, 1973; Morcos and Moustafa Hassan, 1976). The latter layer extends from 150 m down to 400 m and is distinguished by an intermediate maximum salinity. The two upper layers undergo seasonal variation and become indistinguishable during winter. During spring only two layers are found: a surface layer, of high temperature and low salinity and a layer with winter water characteristics. During autumn the distribution of the water masses is transitional between summer and winter conditions. The sources and mode of formation of the layer of intermediate maximum salinity were investigated by Morcos, 1967b, 1972a and Morcos and Moustafa Hassan, 1976. A secondary source for the formation of the intermediate water is detected in the southern Levant Sea. This water has more heterogeneouscharacteristics in the Levant than in the other basins of the Mediterranean, indicating various source regions with respect to space and time. By mixing, these waters acquire more homogeneity on spreading towards the Ionian Sea, and are recognized as a well-identified water mass west of the Strait of Sicily.

The average variation of the sea level along the coast may approach 80 cm (Mobarek et al., 1966; Sharaf El Din and Rifat, 1968); during storms, this variation may reach about 120 cm. The tidal harmonic constituents obtained from a one-month record at Damietta in 1965 show the lunar semi-diurnal component to be the most important. The salient features of the currents along the Egyptian coast are similar to those in the Eastern Mediterranean. Here there is a west to east flow along the coast with an average speed ranging from 0.5 to 1 knot. The velocity is decreased in the bays. This coastal current system is either tidal, density, or wind driven. In addition, there is a nearshore current driven by the wind waves in and near the breaker zone. Along the coast, the tidal currents are weak relative to littoral and coastal currents.

Current measurements by the Suez Canal Authority show that the littoral current reaches a maximum speed of 100 cm/sec^{-1} near Borollos inlet and 150 cm/sec^{-1} at Rosetta (Hilaly, 1971b). The average littoral current was 28 cm/sec^{-1} at Ras al-Barr, 40 at Rosetta, and 35 at Borollos inlet (Mobarek, et al., 1966, Hilaly, 1971a). During stormy periods this circulation pattern is probably seriously affected.

The circulation and salinity distribution in the Suez Canal has a negligable effect on the physical oceanography of the Eastern Mediterranean. However, they greatly influence its ecosystem through the exchange of organisms between the Red Sea and the Mediterranean. Recent investigations of the Suez Canal were made by 13 monthly cruises during 1953/55 by Morcos (1960a), five monthly cruises in 1966-67 by El-Sabh (1969) and El-Sharkawi (1969) and three monthly cruises in 1964/1966 (Morcos, 1967a, 1975 and Morcos and Gerges, 1974). Fortnightly cruises in the Suez Bay were made in 1966-1967 by Meshal (1967). Hydrographic conditions and evaporation from the Bitter Lakes were discussed by Miller and Munns (1974), taking into consideration the observations of ATLANTIS II in July 1963 and February 1965 and the CHAIN (October and November 1966).

The tidal currents and mean sea level in the Suez Canal were studied by Morcos (1960b); Morcos and Gerges (1974); and Sharaf El Din (1975). The effect of the Aswan High Dam on the current regime in the Suez Canal was discussed by Morcos (1967); El-Sabh (1968); Morcos and Messieh (1973a, b); Hassan and El-Sabh (1974, 1975); Morcos (1974, 1975). The physical and chemical characteristics of the exceptionally high salinity of water of the Suez Canal were studied by Morcos and Riley (1966) and Morcos (1967, 1968). An unsually severe density layer (with a salinity of about 332‰) was observed in the Great Bitter Lake in 1974 (Meshal, 1975; Tolbert, 1976). The salinity of the Suez Canal water has decreased greatly since its opening in 1869. A study by Morcos (1972b) provides an examination of the older data of salinity, density and chemical composition of the Suez Canal waters during and after its opening in 1869. Tables for computation of the salinity and density of the Canal waters were published by Morcos, 1960c, 1967, 1968b and Morcos and El-Kirsh, 1968.

E. GEOLOGICAL INVESTIGATIONS ALONG THE MEDITERRANEAN COAST OF EGYPT

Considerable marine geological investigations have been carried out in the Eastern Mediterranean Sea. The earliest work was done by the R/V ENDEAVOUR during the years 1919-1922. It resulted in the construction of a general bathymetric and a rough sediment distribution chart, presented by D'Arrigo (1936), for the shelf area off the Nile Delta.

During the Swedish deep-sea expedition (1947-1948), 16 long cores and 60 surface dredgings were collected from the Eastern Mediterranean and the Aegean Sea. The tephra (volcanic ash), mineralogy, microfauna and general characteristics were subsequently studied in 12 of these cores by Mellis (1954), Duplaix (1958), and Olausson (1961). Another twently long cores were collected by the R/V VEMA and were examined and logged at Lamont Geological Observatory. The cores collected by both the ALBATROSS and VEMA and were examined and logged at Lamont Geological Observatory. The cores collected by both the ALBATROSS and VEMA ranged up to 10 meters and covered a broad belt between the Nile Delta and the vicinity of Crete and Rhodes. They show that the top 10 m of the Nile core consist mostly of grey lutite.

Emery <u>et al</u>. (1966) presented the bathymetry of the Eastern Mediterranean based on the marine geological investigations of the R/V CHAIN (1959) and the Russian R/V ACADEMIC S. VAVILOV during the years 1961-1963. They came to the conclusion that the Mediterranean Ridge is of tectonic origin and that it constitutes a dam against sediments which are introduced by the Nile River and then carried seaward, probably by the general diffusion and turbidity currents.

A recent summary of seismic information by the CIM Group in Monaco shows that some seismic refraction work has been done in the Eastern Mediterranean where a series of tracks north of the Nile cone were made by the Russian R/V ACAD. ARCHANGELSKY and R/V ACAD. VAVILOV in 1969.

Preliminary marine geological studies along the Mediterranean coast of Egypt were started by Steuer (1935), who gave a general description of the bottom topography and the type of sediments in the fishery grounds near Alexandria. Attention has also been given to the shelf sediments along the Mediterranean coast of Egypt. Mohamed (1968) worked on the mechanical, chemical and mineralogical analysis of the recent sediments covering the shelf off the Nile Delta. Later he presented a detailed study of the foraminifera in the sediments covering the same area (Mohamed, 1972). Moussa (1973) carried out a detailed textural, chemical and mineralogical study of bottom sediments of Abu Qir Bay. El-Sayed (1974) studied the type and distribution of bottom sediments covering the inner shelf area off Alexandria, extending between El-Agami and Abu Qir headlands. Shelf and beach samples were subjected to grain size and chemical analysis to determine the carbonate content, organic matter and total phosphorus contents. Mineralogical analysis was carried on these sediments for identification of different mineral assemblages. Interrelations between the texture, chemistry and mineralogy of sediments were discussed with reference to the environmental conditions in an attempt to reveal the process affecting the pattern of sediment type and distribution in the area. Vatova (1935), El-Wakeel (1964) and El-Awadry (1972) have all studied sediments from the eastern and western harbours of Alexandria.

Considerable geological work has been carried out along the Mediterranean coast of Egypt. The presence of black sands on the beaches of Egypt was first mentioned by Ball (1939). Davidson (cf. Shukri, 1950) described the different localities of black sand concentration along the Egyptian coast.

Additional research on black beach sands was conducted by Nakhla (1958), Higazy and Naguib (1958) and El-Boseily (1965). Results include depositional mechanisms, quantities and economic values.

Hilmy (1951) studied beach sand along the entire Mediterranean coast of Egypt. He divided the coast arbitrarily into three parts according to topographical and lithological characteristics. The mechanical analysis and mineral composition of sand deposits along the Mediterranean coast between Rosetta and Bardia were studied by Shukri and Philip (1956). Said and Kamel (1956) studied the foraminiferal composition of the beach sands between Rosetta and Bardia and were able to differentiate the area into fou zones, each having its own faunal characteristics. The geomorpholoty of the deltaic coastal plain between Rosetta and Port Said was studied by Said (1958), who concluded that this plain is the result of alluvial advance of the coast. Butzer (1960) worked on the Pleistocene shore lines of the Gulf of Arabs, west of Alexandria, and questioned the accepted sequence of Pleistocene shore lines southwest of Alexandria. Soliman (1964) studied the primary structure of a six kilometer strip along the beach to the east of the Rosetta mouth.

The shore dynamics and the morphology of the Nile Delta shores were studied by El-Sabarouti (1973). Nawar (1973) worked on the upper Pleistocene and Holocene history of formation of the Nile Delta. The group of geologists at the Coastal Research Branch of the Institute of Oceanography and Fisheries have been studying the Mediterranean coast of Egypt for the last three years through a UNDP Project. They have collected considerable data including sediment samples and have mapped parts of the coast which will be compared with a map of the coastline prepared in 1922. So far their work has been limited by ship facilities, so they have only progressed offshore to a depth of about ten meters.

The shallow brackish-water lakes situated along the Mediterranean coast of Egypt have received attention in the last few years. They are of particular importance in that they produce about 60% of the annual fish catch of the country. With the exception of Lake Maryut, these lakes are connected to the Mediterranean Sea through narrow openings. The staff members of both the Institute of Oceanography and Fisheries, Alexandria and the Oceanography Department, Alexandria University, collaborated in a series of research programmes for the study of the hydrography, chemistry, biology and bottom sediments in these lakes. El-Wakeel and Wahby (1970 a) studied the texture and chemistry of Lake Maryut sediments. They investigated the type and distribution of the sediments, as well as the content and distribution of carbonates, organic matter, phosphorous and iron in the bottom sediments. The bottom sediments of Lake Manzalah were subjected to mechanical and chemical analysis by El-Wakeel and Wahby (1970 b). Interrelations between the grain size, carbonate, organic matter, phosphorous and available iron were studied. Studies on the type and distribution of bottom sediments as well as the ostracoda and foraminifera in grab and core sediments of Lake Idku and Lake Borullos are currently being conducted (Zazou, El-Wakeel, and Abdou, in preparation). A joint Egyptian-American research programme to study the Nile cone and Nile Delta was carried out on R/V CHAIN, in February-March 1975.

APPENDIX III

REVIEW OF FACILITIES IN PARTICIPATING COUNTRIES

The following paragraphs outlining the marine research facilities in existence among participating countries are not necessarily comprehensive nor complete. The information was compiled from that made available by the participants from the respective countries. Without exception, these countries showed enthusiasm towards furthering the type of collaboration and scientific endeavours discussed during the Workshop regardless of their own national facilities.

A. EGYPT

Organized activities in marine sciences started in Egypt in 1931 with the establishment of: (1) the Marine Biological Station of Ghardaqa (Red Sea), under affiliation with Cairo University, and (2) the Alexandria Institute of Hydrobiology and Fisheries, under the authority of the Fisheries Directorate. Both have carried out basic and applied research on the flora, fauna, and ecology of local marine environments as reported in Publications of the Marine Biological Station of Ghardaqa and Notes and Memoirs of the Alexandria Institute.

The two institutes served as centres for training scientists from Egypt and other Arab countries, and hosted experts from all over the world. In 1933-1934, Egypt participated in the John Murray Expedition to the Indian Ocean by sponsoring Egyptian scientists from these two institutes and by contributing the vessel MABAHISS.

1. The University of Alexandria

In 1948, the University of Alexandria founded a Department of Oceanography within its Faculty of Science.

Academic composition :

- 4 professors, two for biological oceanography, 1 chemical and 1 geological,
- 5 assistant professors
- 2 lecturers
- 5 assistant lecturers (M. Sc. graduate), four of them are on study leaves abroad for longer or shorter periods.
- 5 demonstrators.

Facilities :

One motor-boat, 26 feet long, 25 H.P., fit for coastal survey. Equipment for teaching, research and field work, including reversing and insulated water bottles, deep-sea thermometers, current meters, BT Clarke-Bumpus samples, plankton nets, Ekmann and other types of bottom samplers. Laboratory equipment, for spectrophotometry and flamephotometry.

Training :

A graduate degree, Diploma of Higher Studies in Oceanography, was offered to students of the biological sciences, chemistry, and geology. The two-year programme involved courses in physico-chemical and biological oceanography and fisheries.

Since 1966, a B. Sc. in biological oceanography has been offered for students having studied chemistry and biology for the first two academic years. The upper division courses include studies in plankton and benthic organisms, marine ecology, physio-ecology and zoogeography, ichthyology and fisheries, along with courses in physical and chemical oceanography and submarine geology.

In 1971, the curriculum was once more modified and a B. Sc. Physical Oceanography was established for under-graduate candidates having completed two academic years in physics and mathematics. The Biological Oceanography B. Sc. was expanded to a B. Sc. in General Oceanography, providing equal shares for the three major disciplines : Marine Biology, Marine Chemistry and Geology. Students in basic sciences wishing to be trained in marine sciences were allowed to prepare the Diploma of Higher Studies, now reduced to one year and restricted to one of the four specialities : Biological, Chemical, Physical or Geological Oceanography.

Approximately 80 B. Sc. and 100 Diploma students have graduated from the Department since it was established. Most of them have joined the Institute of Oceanography and Fisheries and are working in one of its branches either marine or inland. Others were appointed within the Department itself.

Graduate students, either B. Sc. or Diploma, wishing to specialize further, are entitled to prepare the M. Sc. in the Department. Registered candidates for the M. Sc. follow more advanced courses for two terms as a partial fulfillment for this degree, before starting on their research projects. Finally, they can register for the Ph. D. programme. A total of 5 Ph. D. and 31 M. Sc. candidates have graduated from the Department in the following specializations:

- 7 in marine plankton and bottom fauna
- 8 in marine sediments, chemistry and hydrography
- 11 in limnology
- 10 in ichtyology and fisheries biology.

Research Programme

Research conducted by the Department includes the following areas:

- studies of the current regimes and near-shore circulations of the Egyptian Mediterranean waters,
- studies on the chemical characteristics of the neritic waters and the effects of fresh water inflow,
- estimations of productivity of the area off the Nile Delta in the post-Aswan High Dam condition,
- qualitative and quantitative studies of the littoral benthic communities,
- effects of pollutants in the marine environments around Alexandria, and
- the biological exchange between the Mediterranean and Red Sea.

International Collaboration

Collaboration with Unesco on a pollution project in the vicinity of Alexandria is expected to start soon.

2. The Institute of Oceanography and Fisheries

In 1960 the Institute of Oceanography and Fisheries was created from the former Marine Biological Station and the Institute of Hydrobiology. The new Institute is administratively under the Academy of Science and issues its own publication, the Bulletin of the Institute of Oceanography and Fisheries.

Staff :

The scientific staff of the Institute includes 112 scientists distributed in its different departments and sections (Physical, Chemical, Geological, Hydrobiological, Invertebrate, Fisheries Biology, a reference centre and the Delta Lake centres). The staff has 22 members with Ph. D. degrees, 24 with M. Sc. degrees, and 19 on graduate study leave abroad.

Facilities :

The Institute occupies a three floor building situated close to the sea at the western extremity of the Eastern Harbour in the neighbourhood of Fort Kayet Bay.

The building contains :

- well equipped laboratories for the different disciplines of Oceanography and Fisheries
- a library which possesses the largest collection of publications in marine science in Egypt,
- the reference collection centre, and
- an aquarium.

Also, the Institute has three research centres located on the coastal Delta Lakes.

The Institute has two research vessels : FARAS-EL-BAHR, 22 m long and 160 H.P., provided with equipment for oceanographic and fisheries work. EL-BAHNASY, a small trawler, 13 m long, suitable for coastal trawling.

Research Programmes :

The Institute is conducting research in the following areas:

- productivity and stock assessment of Lake Idku, Lake Burullus and Lake Menzalah,
- shrimp culture in Lake Idku,
- sources of fry (mainly grey mullets) for transport to inland lakes and fish farms,
- studies on the sardines and other pelagic fish in the Mediterranean, west of Rashid. (This is a three-year project which includes also all other disciplines of oceanographic studies).

International Collaboration :

The Institute is taking part in some international activities such as CIM (Co-operative Investigations in the Mediterranean) and the IGOSS (Integrated Global Ocean Station System) Pilot Project on Marine Pollution.

B. LEBANON

Institutions conducting marine research :

1. The National Research Council Centre at Jounieh
2. American University of Beirut.

Research Scientists: 8 (combined).

Fields of research :

1. Fisheries (biology, parasitology)
2. Biological oceanography (plankton physiology, plankton cultures)
3. Marine pollution
4. Marine geology

Special Facility :

R/V SITA III (owned by the National Research Council)

C. LIBYA

Institutes conducting marine research :

1. Marine Fisheries Research Centre (MFRC) of Tripoli
2. University of Tripoli

Research Scientists :

11 (Marine Fisheries Research Centre)

Fields of Research :

The MFRC is conducting applied research in the following areas:

1. Fisheries
2. Biochemistry
3. Chemical oceanography
4. Biological oceanography (benthic fauna, phytoplankton and zooplankton). The university is responsible for more basic research and for providing lectures in selected marine sciences.

Facilities :

The MFRC has a new building and is well equipped with basic equipment. It has two vessels, one equipped for hydrobiology, and marine geology and the other for fishery. Recently it has conducted several joint cruises in its waters with vessels from other countries.

D. MALTA

Institute conducting marine research :

Royal University of Malta

Fields of research :

1. Biological oceanography (planktonic, benthic)
2. Chemical oceanography
3. Marine pollution (oil spills)

E. SYRIA

Syria is building a Marine Research Centre in Latakia under the auspices of the National Commission for Oceanography of the Supreme Council of Science. None of the three Syrian Universities offer specific courses in marine research, although a number of Syrians are taking courses in foreign countries. There are at present two marine biologists in the country.

F. TUNISIA

Institute conducting marine research :

Institut National Scientifique et Technique d'Océanographie et des Pêches (INSTOP) in Salambo.

Fields of research :

1. Fisheries (physiology, aquaculture)
2. Biological Oceanography (benthic, planktonic)
3. Marine pollution

Facilities :

1. Three research vessels
2. Extensive laboratories and a library. A large annex is being completed this year.

APPENDIX IV : REFERENCES

1. GENERAL LITERATURE ON SYSTEMS ECOLOGY

Forrester, J. 1971. World dynamics. Cambridge, MA, Wright-Allen Press. 142 p.

Gilpin, M.E. 1975. Group-selection in predator-prey communities. Princeton, Princeton Univ. Press.

Hall, C.A.S.; Day, J.W. (eds.) 1977. Models in ecology : theory and case studies. New York, John Wiley and Sons.

Koestler, A.; Smythies, J.R. (eds.) 1969. Beyond reductionism. New York, Mac Millan.

Levin, S.A. (ed.) 1975. Ecosystems analysis and prediction. Philadelphia, Soc. Industr. Appl. Math. Press.

Levins, R. 1966. The strategy of model building in population biology. Amer. Scientist, vol. 54, p. 421-31.

Levins, R. 1968. Evolution in changing environments. Princeton, Princeton Univ. Press. 120 p.

Lotka, A.J. 1925. Elements of physical biology. Baltimore, Williams and Wilkins, 460 p. (Revised edition by Dover Publ., New York, 1956).

Lugo, A.E.; Snedaker, S.C.; Bayley, S.; Odum, H.T. 1971. Models for planning and research for the South Florida environmental study. In : Final report on contract no. 14-10-9-900-363 to the National Park Service, U.S. Dept. of the Interior, and the Center for Aquatic Sciences, Univ. of Florida. 157 p.

McHarg, I. 1971. Design with nature. Long Island, Doubleday : Natural History Press, 197 p.

Margalef, R. 1968. Perspective in ecological theory. Chicago, Univ. Chicago Press. 111 p.

May, R.M. 1973. Stability and complexity in model ecosystems. Princeton, Princeton Univ. Press, 235 p.

Maynard-Smith, J. 1974. Models in ecology. Cambridge, Cambridge Univ. Press, 146 p.

Nihoul, J.C.J. (ed.) 1975. Modelling of marine systems. New York, Elsevier, 272 p.

Odum, H.T. 1967. Biological circuits and the marine systems of Texas. In : Olson, T.A.; Burgess, F.J. (eds.) : Pollution and marine ecology, New York, Wiley-Interscience Publishers, 364 p.

Odum, H.T. 1971. Environment, power and society. New York, Wiley Interscience, 331 p.

Odum, H.T. 1972. An energy circuit language for ecological and social systems : its physical basis. In Patten, B.C. (ed.) : Systems analysis and simulation in ecology, vol. 2, New York, Academic Press, 592 p.

Odum, H.T. 1977. An introduction to energetics and systems ecology. New York, McGraw-Hill.

Patten, B. 1971 through 1975 (ed.) Systems analysis and simulation in ecology. Vols. I, II, III. New York, Academic Press.

Pielou, E.C. 1969. An introduction to mathematical ecology. New York, Wiley-Interscience, 286 p.

Rosen, R. 1970. Dynamical systems theory in biology. Vol. I. New York, John Wiley and Sons.

Steele, J.H. 1974. The structure of marine ecosystems. Cambridge, Harvard Univ. Press, 128 p.

Van Dyne, G. 1973. Resource management and systems analysis. New York, McGraw-Hill.

Von Bertalanffy, L. 1971. General systems theory. New York, Dover Publ.

Walters, C. 1971. Systems ecology : the systems approach and mathematical models in ecology. In : Odum, E.P. Fundamentals of ecology. Philadelphia, W.B. Saunders Co., 574 p.

Watt, K.E.F. (ed.) 1967. Systems analysis in ecology. New York, Academic Press, 276 p.

Watt, K.E.F. 1968. Ecology and resource management. New York, McGraw-Hill, 450 p.

Watt, K.E.F. 1975. Principles of environmental science. New York, John Wiley and Sons.

Wiegert, R. 1975. Simulation of ecological systems. Ann. Rev. Ecol. Systematics, Vol. 5.

Woodwell, G.; Smith, F.E. (eds.) 1969. Diversity and stability in ecological systems. Upton, NY, Nat. Lab. Publ. no. 22, 264 p.

2. LITERATURE PERTINENT TO THE EGYPTIAN MEDITERRANEAN WATERS

General

Aleem, A.A. 1969. Marine resources of the United Arab Republic. Stud. Rev. Gen. Fis. Counc. Mediter., no. 43, p. 1-22.

Aleem, A.A. 1972. Effect of river outflow management on marine life. Mar. Biol. vol. 15, p. 200-8.

Halim, Y. 1975. The Nile and the East Levantine Sea, past and present. In: Recent researches in estuarine biology. New Delhi, R. Natarajan, p. 76-84.

Biological Oceanography

Plankton

Abdallah, R.R. 1975. The effect of some nutrients on the growth of Synechocystis aquatilis. (unpublished manuscript).

Dorgham, M.M.S. 1974. Plankton diatoms of Port-Said area. M. Sc. thesis, Alex. Univer. (unpublished manuscript).

Dowidar, N.M. 1971. Distribution and Ecology of Ceratium egyptiacum Halim and its validity as indicator of the current regime in the Suez Canal. Int. Rev. Gesamt. Hydrobiol. vol. 56 no. 6, p. 957-66.

Dowidar, N.M., 1972. Morphological variations in Ceratium egyptiacum in different natural habitats. Mar. Biol. no. 16, p. 138-49.

Dowidar, N.M. 1974a. Phytoplankton of the Suez Canal. Rapp. Comm. int. Mer. Medit. vol. 22, no. 9, p. 59.

Dowidar, N.M. 1974b. Tintinnids from the Suez Canal. Rapp. Comm. int. Mer. Medit. vol. 22, no. 9, p. 123-4.

Dowidar, N.M. 1974c. The phytoplankton of the Mediterranean waters of Egypt. A. A check list of the species recorded. Bull. Inst. Oceanogr. Fish. Cairo, vol. 4, p. 319-44.

Dowidar, N.M.; Aleem, A.A. 1967. Phytoplankton production in relation to nutrients along the Egyptian Mediterranean coast. Trop. Oceanogr. Miami, vol. 5, no. XX, p. 305-23.

Dowidar, N.M.; El-Maghraby, A.M. 1970a. The neritic zooplankton of the southeastern Mediterranean at Alexandria. I. Distribution and ecology of the zooplankton organisms with special reference to Copepoda. Bull. Inst. Oceanogr. Fish., Cairo, vol. 1, p. 225-73.

Dowidar, N.M.; El-Maghraby, A.M. 1970b. The neritic zooplankton of the southeastern Mediterranean at Alexandria. II. Consideration of the total zooplankton community. Bull. Inst. Oceanogr. Fish., Cairo, vol. 1, p. 275-303.

Dowidar, N.M.; El-Maghraby, A.M. 1971 . Observation on the neritic zooplankton community in Abu Qir Bay during the flood season. Rapp. Comm. int. Mer. Medit. vol. 20, no. 3, p. 385-9.

Dowidar, N.M.; El-Maghraby, A.M. 1973a. Observations on the zooplankton community in the Egyptian Mediterranean waters. Rapp. Comm. int. Mer. Medit. vol. 21, no. 8, p. 527-30.

Dowidar, N.M.; El-Maghraby, A.M. 1973b. Notes on the occurrence and distribution of some zooplankton species in the Mediterranean waters of U.A.R. Rapp. Comm. int. Mer. Medit. vol. 21, no. 8, p. 521-5.

El-Maghraby, A.M. 1964. The development stages and occurrence of the copepod Euterpina acutifrons Dana in the marine environment of Alexandria. Annals and Mag. of Nat. Hist., Ser. 13, no. 7, p. 223-33.

El-Maghraby, A.M. 1965. The seasonal variation in length of some marine plankton copepods from the Eastern Mediterranean at Alexandria. Crustaceana, vol. 8, no. 1, p. 37-47.

El-Maghraby, A.M.; Dowidar, N.M. 1970. Ecological affinities of some pelagic copepods from the Mediterranean water of U.A.R. In : Journées Etud. planctonol. CIESM, p. 79-82.

El-Maghraby, A.M.; Halim, Y. 1964. A quantitative and qualitative study of the plankton of Alexandria waters. Hydrobiol. vol. 25, no. 1-2, p. 221-38

Guerguess, S.K. 1970. Zooplankton studies in UAR Mediterranean waters with special reference to the Chaetognatha. M. Sc. thesis, Alex. Univer.

Guerguess, S.K.; Halim, Y. 1973. Chaetognathes du plancton d'Alexandrie. II. Un spécimen mûr de Sagitta neglecta Aida en Méditerranée. Rapp. Comm. int. Mer. Medit. vol. 21, no. 8, p. 497-8.

Halim, Y. 1955. Note sur Péridinium Tregouvoffi n. sp. (Dinoflagellé). Bull. Inst. Oceanogr. Fish., Cairo.

Halim, Y. 1960a. Observations on the Nile bloom of phytoplankton in the Mediterranean. J. Cons. int. Explor. Mer, vol. 26, no. 1, p.57-67.

Halim, Y. 1960b. Alexandrium minutum n. gen., n. sp., Dinoflagellé provocant des 'eaux rouges'. Vie et Milieu, vol. 11, no. 1, p. 102-5.

Halim, Y. 1963. Microplancton des eaux égyptiennes. Le Genre Ceratium schrank (Dinoflagellés). Rapp. Comm. int. Mer Medit., vol. 17, no. 2, p. 495-502.

Halim, Y. 1965a. Microplancton des eaux égyptiennes. II-Chrysomonadines, Ebriediens et Dinoflagellés nouveaux ou d'intérêt biogéographique. Rapp. Comm. int. Mer Medit., vol. 18, no. 2, 373-9.

Halim, Y. 1965b. Observations on Mediterranean Dinoflagellates. CIESM, Comité du plancton, Comm. 136. Rome.

Halim, Y. 1969a. On Gessnerium mochimaensis Halim. Int. Rev. Gesamt. Hydrobiol., vol. 54, no. 4, p. 619.

Halim, Y. 1969b. Plankton of the Red Sea. Oceanogr. Mar. Biol. vol. 7, p. 231-75.

Halim, Y. 1970. Microplancton des eaux égyptiennes. III - Espèces indo-pacifiques ou érythréennes à l'extrême nord du Canal de Suez. Journées Etudes planctonol. CIESM, Monaco, p. 57-9.

Halim, Y. 1977. Marine biological studies in Egyptian Mediterranean Waters : a review. In : Symposium on the Eastern Mediterranean Sea, Malta, 1973. Acta Adriat., vol. XVIII, no. 1-23, p. 29-38.

Halim, Y.; Abu El-Ez, S.; Guerguess, S.K. 1974. Appendiculaires d'Alexandrie et des régions avoisinantes. Rapp. Comm. int. Mer Medit., vol. 22, no. 9, p. 113-4.

Halim, Y.; Guerguess, S.K., 1973. Chaetognathes du plancton d'Alexandrie: I. Généralités. S. friderici, Rapp. Comm. int. Mer Medit., vol. 21, no. 8, p. 493-6.

Halim, Y.; Samaan, A.; Salah, M. and Zaghloul, F. 1975. Estuarine plankton of the Nile and the effect of fresh-water. Phytoplankton. Symposium on the effect of fresh water outflow on biological processes in fjords and coastal waters, 1974. Geilö, Norway, p. 153-64.

Hassan, A.K.A. 1973. Systematic and ecological study of Dinoflagellates in the area of Alexandria. M. Sc. thesis, Alex. Univer. (unpublished manuscript).

Hopkins, T.S.; Spiropoulos, C. and Lambiri M. 1976. Variability in winter surface chlorophyll distributions, Saronikos Gulf. Rapp. Comm. int. Mer Medit. vol. XVIII, no. 9.

Nival, P.; Malara, G.; Charra, R.; Nival, S.; Palazzoli, I. 1972. Evolution annuelle des biomasses de phytoplancton et de zooplancton dans la mer ligure. C.R. Acad. Sc., Paris, vol. 275, p. 1295-8.

Salah, M. 1963. Plankton investigations of the Egyptian Mediterranean coast. Notes and memoirs of Alexandria Institute of Oceanography and Fisheries, no. 68, 44p.

Salah, M. 1967. Description of new planktonic diatoms from Egypt. Annal. Biol. Hungaria, no. 34, p. 179-89.

Salah, M. 1968. Notes on new planktonic diatoms from Egypt. Hydrobiol. vol. 31, no. 2, p. 231-40.

Salah, M. 1971. A preliminary check-list of the plankton along the Egyptian Mediterranean coast. Rapp. Comm. int. Mer Mediter., vol. 20, no. 3, p. 317-22.

Salah, M. 1976. New planctonic diatoms from Abu Qir Bay, Alexandria, Egypt, Bull. Inst. Oceanogr. Fish. Cairo. (in press).

Salah, M.; Tamas, G. 1969. A new Surirella from Egypt. Acta Acad. Scient. Hungariae, vol. 14, no. 3-4, p. 369-71.

Salah, M.; Tamas, G. 1970. General preliminary contribution to the plankton of Egypt. Bull. Inst. Oceanogr. Fish., Cairo. vol. 1, p. 305-37.

Sournia, A. 1973. Primary production in the Mediterranean. Cooperative Investigation of the Mediterranean Newsletter, vol. 5, p. 1-128.

Sultan, H.A. 1975. Preliminary investigation on the primary production of marine phytoplankton of the Egyptian Mediterranean coast around Alexandria region. M. Sc. thesis, Alex. University (unpublished manuscript).

Benthos

Balss, H. 1936. The fishery gounds near Alexandria. 7. Decapoda. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 15, 67p.

Billard, A. 1936. The fishery grounds near Alexandria. 6. Hydroidea. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 13, 11p.

Broch, H. 1935. The fishery grounds near Alexandria . 3. Cirripeds. Notes and memoirs of Alexandria Institute of Hydrobiology, no. 10, 5p.

Burton, M. 1936. The fishery grounds near Alexandria. 9. Sponges. Notes and memoirs of Alexandria Institute of Hydrobiology, no. 17, 28p.

Dowidar, N.M. 1973. Family penaeidae from the Mediterranean waters of Egypt. Rapp. Comm. int. Mer Medit. vol. 22, no. 4.

Dowidar, N.M.; Hassan, A.K. 1973. Notes on the bivalve and gastropod fauna in the region of Abu Qir Bay (Alexandria). Rapp. Comm. int. Mer. Medit., vol. 22, no. 4, p. 71-2.

El-Nasry, M.M. 1973. Biological study on the Crustacea associated with fouling growths in the Eastern Harbour, Alexandria . M. Sc. thesis, Alex. Univ. (unpublished manuscript).

Fauvel, P. 1937. Les fonds de pêche près d'Alexandrie. II. Annelides Polychaetes, Notes and memoirs of Alexandria Institute of Hydrobiology, no. 19, 60p. 2 plates.

Fox, H. 1926. Cambridge Expedition to the Suez Canal. I. General part. Trans. Zool. Soc.,London. Vol. 22, no. 1, p. 1-64.

Ghobashy, A.F.A. 1974. Growth rate of four barnacles in the Eastern Harbour of Alexandria. Bull. Fac. Sci. Mansoura University, vol. 2, p. 1-11.

Ghobashy, A.F.A. 1976a. Seasonal variation and settlement behaviour of the principal fouling organisms in the Eastern Harbour. Bull. Inst. Oceanogr. Fish., Cairo.

Ghobashy, A.F.A.; Selim, S.A. 1976b. Settlement behaviour of the tube worm Hydroides norvegica Gun. in the Eastern Harbour, Alexandria. Bull. Inst. Oceanogr. Fish. Cairo.

Ghobashy,A.F.A.; Selim, S.A. 1976c. Growth of the tube worm Hydroides norvegica Gun. in the Eastern Harbour, Alexandria. Bull. Inst. Oceanogr. Fish. Cairo.

Ghobashy, A.F.A.; Selim, S.A. 1976d. Settlement and growth of Spirorbis corrugatus Montagu in the Eastern Harbour of Alexandria. Bull. Inst. Oceanogr. Fish., Cairo.

Harrant, H. 1939. Les fonds de pêche près d'Alexandrie. 17. Ascidiacea. Notes and memoirs of Alexandria Institute of Hydrobiology. no . 28, 7p., 5 plates.

Hassan, A.H. 1974. Studies on the Bottom Mollusca (Gastropoda and Bivalvia in Abu Qir Bay). M. Sc. Thesis, Alex. University (unpublished manuscript).

Helfer, H. 1936. The fishery grounds near Alexandria. 8. Pantopoda. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 16, 6p.

Larwood, H.J. 1940. The fishery grounds near Alexandria. 21. Tanaidaceae and Isopoda. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 35, 72p.

Megally, A.H. 1970. Ecological study on marine fouling organisms in the Eastern Harbour, Alexandria . M. Sc. thesis, Alex. University. (unpublished manuscript).

Mortensen, R.; Steuer, A. 1937. The fishery grounds near Alexandria. 13. Echinoderma. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 21, 37p.

O'Donoghue, H.; de Watteville, D. 1939. The fishery grounds near Alexandria. 20. Bryozoa. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 34, 58p.

Schellenberg, A. 1936. The fishery grounds near Alexandria. 10. Amphipoda benthonica. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 18, 27p.

Steinitz, H. 1967. A tentative list of immigrants via the Suez Canal. Israel J. Zool. vol. 16.

Steuer, A. 1935. The fishery grounds near Alexandria. I. Preliminary report. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 8, 18p.

Steuer, A. 1939. The fishery grounds near Alexandria. 19. Mollusca. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 33, 152p.

Vatova, A. 1935. The fishery grounds near Alexandria. 2. A bottom sample taken at Alexandria. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 9, 3p., 1 plate.

Macro-algae

Mohamed, A.F.; Halim, Y. 1952. Agar from Egyptian sea-weeds. Am. J. Bot. vol. 39, no. 9, p. 689-90.

Mohsen, A.F. 1966a. Mineral constituents and total nitrogen content of some marine algae inhabiting the Mediterranean coast of Alexandria. Bull. Fac. Sci. Alex. Univ., vol. 7, p. 211-39.

Mohsen, A.F. 1966b. Studies on the effects of different nutritive media on Cosmarium botrytis. Bull. Fac. Sci. Alex. Univ., vol. 7 p. 201-9.

Mohsen, A.F.; Khalifa, A.F. 1968. Some hydrographic aspects with reference to algae of Lake Maryut Part I. Chlorophyta. Bull. Fac. Sci. Alex. Univ., vol. 8, no. 2, p. 407-25.

Nasr, A.H. 1940a. The marine algae of Alexandria. 1 - A report on some marine algae collected from the vicinity of Alexandria. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 36, 33p., 6 plates.

Nasr, A.H. 1940b. The marine algae of Alexandria . 2 - A study of the occurrence of some marine algae on the Egyptian Mediterranean coast. Notes and memoirs of Alexandria Institute of Hydrobiology. no. 37, 9p. 2 plates.

Nasr, A.H.; Bekheet, I.A. 1970. Effect of certain trace elements and soil extract on some marine algae. Hydrobiol., vol. 36, no. 1, p. 53-60.

Nasr, A.H.; Bekheet, I.A.; Ibrahim, R.K. 1968. The effect of different nitrogen and carbon sources on aminoacid synthesis in Ulva, Dictyota, and Pterocladia. Hydrobiol., vol. 31, no. 1, p. 7-16.

Nasr, A.H.; Mohsen A.F. 1961a. Distribution and life history of Ectocarpus siliculosus at Maadiah district of Lake Edku. Fourth Arab League Science Congress, Cairo, 1960, p. 117-24.

Nasr, A.H.; Mohsen, A.F. 1961b. Effect of salinity and temperature on the growth and reproduction of Ectocarpus siliculosus in Lake Edku. Fourth Arab League Science Congress, Cairo, 1960, p. 125-54.

Nasr, A.H.; Mohsen, A.F.; Bekheet, I.A. 1966a. Agar production from Egyptian agarophytes. Bull. Fac. Sci. Alex. Univ. vol. 7, p. 99-113.

Nasr, A.H.; Mohsen, A.F.; Bekheet, I.A. 1966b. Effect of salinity and temperature variations on Pterocladia capillacea. Hydrobiol., vol. 28, no. 3-4, p. 395-400.

Nasr, A.H.; Mohsen, A.F.; Bekheet, I.A. 1968. Effect of some hydrographic factors on the natural growth of some marine algae at the coast of Alexandria. Bull. Fac. Sci. Alex. Univ. vol. 8, no. 2, p. 365-78

Nasr, A.H.; Mohsen, A.F.; Metwalli, A. 1972a. Effect of different salinities on growth, reproduction, aminoacid synthesis, fat and sugar contents of Ulva fasciata Delile. Bot. Mar. vol. 15, p. 177-81.

Nasr, A.H.; Mohsen, A.H.; Metwalli, A. 1972b. Effect of different carbon sources on growth, reproduction, aminoacid synthesis, fat and sugar content in Ulva fasciata Delile. Bot. Mar. vol. 15, p. 182-5.

Samaan, A.A. 1960. Extraction of agar-agar from drifted sea-weeds. Notes and memoirs of Alexandria Institute of Hydrobiology, no. 60, 6 p.

Al-Kholy, A.A.; El-Wakeel, S.K. (ed), 1975. Fisheries of the South-Eastern Mediterranean Sea along the Egyptian coast, Soviet-Egyptian Expedition, 1970-72. Bull. Inst. Oceanogr. Fish. (Alexandria), vol. 5.

Dowidar, N.M.; Morcos, S.A., 1976. Observations on the chemical properties of polluted waters in Alexandria region (A.R.E.). Rapp. Comm. int. Mer Medit., vol. 23, no. 7, p. 31-3.

Dowidar, N.M.; Morcos, S.A.; Saad, M.A.R.; El-Samra, M.I. 1977. Hydrographic Observations on Pollution in Abu Qir Bay, Alexandria. IBP/PM Symposium on the Eastern Mediterranean Sea, Malta, 1973, Acta Adriat. vol. XVIII, no. 1-23, p. 379-96.

El-Kirsch, A.L.M. 1969. Study of some hydrographic factors in the water of Alexandria region. M. Sc. thesis, University of Alexandria, 136 p. (unpublished manuscript).

El-Rayis, O.A. 1973. Cycle of nutrient salts in Mediterranean sea water off Alexandria . M. Sc. thesis, Alexandria University. (unpublished manuscript).

El-Sabh, M.I. 1968. The effects of Aswan High Dam on the distribution of salinity in the Suez Canal. Nature, Lond. vol. 218, p. 758-60.

El-Sabh, M.I. 1969. Seasonal hydrographic variations in the Suez Canal after the completion of the Aswan High Dam. Kiel. Meeresforsch., vol. 25, p. 1-18.

El-Sharkawi, S.M. 1969. Hydrography of the Suez Canal Lakes . M. Sc. thesis, Cairo University, 154 p.

Emara, H.I. 1969. Distribution of oxygen, nutrient salts and organic matter in the Mediterranean Sea off the Egyptian coast . M.Sc. thesis, Alexandria University.(unpublished manuscript).

Emara, H.I.; Halim, Y.; Morcos, S.A. 1972. Oxygen, phosphate, and oxidizable organic matter in the Mediterranean waters along the Egyptian Coast. Rapp. Comm. int. Mer. Medit. vol. 21, no. 7, p. 345-7.

Gerges, M.A. 1974. Analogy in the oceanographic processes in the Mediterranean sea and estuaries. In "Processus de formation des eaux océaniques profondes en particulier en Méditerranée Occidentale". Colloq. Inter. du C.N.R.S., no. 215 , Paris.

Gerges, M.A. 1976. The damming of the Nile River and its effects on the hydrographic conditions and circulation pattern in the southeastern Mediterranean and the Suez Canal. IBP/PM - Unesco Symposium on the Eastern Mediterranean Sea, Malta, 1973, Acta Adriat., vol. XVIII, no. 1-23, p. 177-91.

Gerges, M.A. 1977. Preliminary results of a numerical model of circulation using the density field in the Eastern Mediterranean. IBP/PM - Unesco Symposium on the Eastern Mediterranean Sea, Malta, 1973, Acta Adriat., vol. XVIII, no. 1-23, p. 163-76.

Gorgy, S. 1966. Les pêcheries et le milieu marin dans le secteur méditerranéen de la R.A.U. Rev. Trav. Inst. Pêches Marit., Nantes, vol. 30, no. 1, p. 25-92.

Gorgy, S; Shaheen, A.H. 1964. Hydrographic results of the Shoyo-Maru Expedition in the Mediterranean and Red Sea. Notes and Memoirs of Alexandria Institute of Hydrobiology, no. 71, 44p.

Halim, Y.; Gerges, M.A.; Saleh, H.H. 1967. Hydrographic conditions and plankton in the Southeastern Mediterranean during the last normal Nile flood (1964). Int. Rev. gesamt. Hydrobiol., vol. 52, no. 2, p. 401-25.

Halim, Y.; Morcos, S.A., 1966. Le rôle des particules en suspension dans l'eau du Nil en crue dans la répartition des sels nutritifs au large de ses embouchures. Rapp. Comm. int. Mer. Medit. vol. 28, no. 3, p. 733-6.

Hassan, E.M.; El-Sabh, M.I. 1974. Change in the current regime in the Suez Canal after reconstruction of Aswan High Dam. Nature, Lond. vol. 248 p.217-8.

Hassan, E.M.; El-Sabh, M.I. 1975. Circulation and salinity distribution in the Southern part of the Suez Canal. Limnol. Oceanogr. vol. 20, p. 667-71.

Hilaly, N. 1971a. Coastal investigations near the Rosetta exit of the River Nile. Suez Canal Authority, Tech. Rep. no. 54, p. 1-60.

Hilaly, N. 1971b. Coastal investigations near the Burullus inlet. Suez Canal Authority, Tech. Rep. no. 55, p. 1-44.

Hilmy, M.E. 1951. Beach sands of the Mediterranean coast of Egypt. J. Sedimentary Petrology, vol. 21, no. 2, p. 109-20.

Kadib, A.A. 1969. Study of the littoral drift at Ras El Barr using fluorescent tracer. Suez Canal Authority, Tech. Rep. no. 42, p. 1-34.

Kadib, A.A. 1971. Improving navigation and shoaling conditions at Damietta Estuary, Arab Rep. of Egypt. Suez Canal Authority, Tech. Rep. no. 58, p. 1-5.

Meshal, A.H. 1967. A physical study of water pollution in Suez Bay (Hydrography of Suez Bay). M. Sc. thesis, Cairo University, 109 p.

Meshal, A.H. 1975. Brine at the bottom of the Great Bitter Lake as a result of closing the Suez Canal. Nature, Lond. vol. 256, p. 297-8.

Miller, A.R.; Munns, R.G. 1974. The Bitter Lake salt barrier. In : L'océanographie physique de la Mer Rouge. IAPSO/UNESCO/SCOR Symp., Paris, 1972. CNEXO Publ. Ser. Actes Colloq. no. 2, p. 295-310.

Mobarek, I.; Kadib, A.A.; El-Ghamry, M. 1966. New Harbour at Damietta field investigations. Suez Canal Authority, Tech. Rep., no. 34, 148 p.

Morcos, S.A. 1960a. Die Verteilung des Salzgehaltes im Suez Canal. Kiel. Meeresforsch. vol. 16, p. 133-54.

Morcos, S.A. 1960b. The tidal currents in the southern part of the Suez Canal. Symposium on Tidal Estuaries. Int. Ass. Phys. Oceanogr., IUGG, Helsinki, 1960. Publication no. 51, Int. Ass. of Scientific Hydrology, Com. of Surface Waters, p. 307-16.

Morcos, S.A. 1960c. Hydrographical Tables for high salinities (from 41.5‰ to 47‰). Bull. Inst. Oceanogr. Monaco, vol. 57, no. 1180, 27 p.

Morcos, S.A. 1967a. Effect of the Aswan High Dam on the Current Regime in the Suez Canal. Nature, Lond., vol. 214, no. 5091, p. 901-2.

Morcos, S.A. 1967b. On the origin of the Mediterranean Intermediate Water. Int. Ass. Phys. Oceanogr. General Assembly, IUGG, Berne, 1967. Abstracts of Papers, vol. V, no. 126.

Morcos, S.A. 1967c. Sigma-Tables for Sea Water of high salinity (from 30‰ to 48‰). Beitr. Meeresk., H. 21, p. 5-14.

Morcos, S.A. 1967d. The chemical composition of sea water from the Suez Canal region. Part I. The Major Anions. Kiel. Meeresforsch., vol. 23, p. 80-91.

Morcos, S.A. 1968a. The chemical composition of sea water from the Suez Canal region. Part II. The Major Cations. Kiel. Meeresforsch., vol. 24, p. 66-84.

Morcos, S.A. 1968b. Substandard Sea Water of any salinity for chlorinity determination. J. Cons. int. Explor. Mer., vol. 31, p. 291-9.

Morcos, S.A. 1972a. Sources of Mediterranean Intermediate Water in the Levantine Sea. In : Arnold L. Gordon (ed.) Studies in Physical Oceanography - A tribute to Georg Wüst on his 80th birthday. New York, Gordon and Breach, vol. 2, p. 185-206.

Morcos, S.A. 1972b. Early investigations of the Suez Canal waters during and after its opening in 1869. Proceedings of the Second International Congress on the History of Oceanography - 1. Proceedings of the Royal Society of Edinburgh, Section B, vol. 72, p. 449-58.

Morcos, S.A. 1974. Change in the current regime in the Suez Canal after reconstruction of Aswan High Dam, Nature, Lond. vol. 248, no. 5444, p. 218-9.

Morcos, S.A. 1975. A transitional stage in the current regime in the Suez Canal. Limnol. Oceanogr., vol. 20, no. 4, p. 672-9.

Morcos, S.A.; El-Kirsh, A.L.M. 1968. Hydrographic Tables for the evaluation of chlorinity analyses based on substandard sea waters having a salinity ranging from 30‰ to 47‰ . Bull. Inst. Oceanogr. Monaco, vol. 67, no. 1378, 14 p.

Morcos, S.A.; El-Rayis, O.A. 1973. The Levantine Intermediate Water, oxygen, and nutrients off Alexandria. Thalassia Jugosl., vol. 9, no. 1/2, p. 13-8. (Also in Rapp. Comm. int. Mer. Medit., vol. 22, no. 8, p. 117).

Morcos, S.A.; Gerges, M.A. 1974. Circulation and mean sea level in the Suez Canal. In : L'océanographie physique de la Mer Rouge , IAPSO/UNESCO/SCOR Symposium, Paris, 1972, CNEXO Publ. Série : Actes de Colloques, Paris, no. 2, p. 267-87.

Morcos, S.A.; Messieh, S.N. 1973a. Change in the current regime in the Suez Canal after construction of Aswan High Dam. Nature, Lond., vol. 242, no. 5392, p. 38-9.

Morcos, S.A.; Messieh, S.N. 1973b. Circulation and salinity distribution in the southern part of the Suez Canal. Limnol. Oceanogr., vol. 18, p. 121-30.

Morcos, S.A.; Moustafa Hassan, H. 1973. Some hydrographic features of the Mediterranean Waters along the Egyptian Coast. Thalassia Jugosl., vol. 9 no. 1/2, p. 227-34.

Morcos, S.A.; Moustafa Hassan, H. 1977. The water masses and circulation in the southern Levant Basin of the Mediterranean. IBP/PM-Unesco Symposium on the Eastern Mediterranean Sea, Malta, 1973. Acta Adriat., vol. XVIII, no. 1-23, p. 193-218.

Morcos, S.A.; Riley, J.P. 1966. Chlorinity, salinity, density and conductivity of sea water from the Suez Canal region. Deep-Sea Research, vol. 13, p. p. 741-49.

Moustafa-Hassan, H. 1969. The hydrography of the Mediterranean waters along the Egyptian coast. M. Sc. thesis, Alexandria University. (unpublished manuscript).

Sharaf El Din, S.H. 1968. The physical factors affecting the water circulation along the Egyptian coast. In : First Arab League Oceanographic Congress, Cairo.

Sharaf El Din, S.H. 1972a. Some aspects of the hydrographic conditions of the Eastern part of the Mediterranean Sea. Rapp. Comm. int. Mer. Medit., vol. 20, no. 4, p. 619-21.

Sharaf El Din, S.H. 1972b. Further studies on the tides and hydrography of Suez Canal and its Lakes. IAPSO/UNESCO/SCOR Symposium on Physical Oceanography of the Red Sea, Paris, Publ. CNEXO, Actes de Colloques, no. 2, p. 289-94.

Sharaf El Din, S.H. 1974a. Longshore sand transport in the surf zone along the Egyptian coast. Limnol. Oceanogr., vol. 19, p. 182-9.

Sharaf El Din, S.H. 1975. Variation of sea level on the Egyptian Mediterranean and Red Sea coasts. Int. Hydrogr. Rev., vol. 52, p. 63-73.

Sharaf El Din, S.H. 1976. Current regime over the continental shelf in front of the Nile Delta. Rapp. Comm. int. Mer Medit. vol. 23, no. 5, p. 71-3.

Sharaf El Din, S.H.; Karam, A.M. 1974. Geostrophic current in the South east sector of the Mediterranean Sea. IAPSO/UNESCO/SCOR Symposium, Paris, 1972. CNEXO Publ. Série : Actes de Colloques, Paris, no. 2, p. 267-87.

Sharaf El Din, S.H.; Rifat, E.M. 1968. Variation of sea level at Alexandria. Int. Hydrogr. Rev., vol. 45, p. 175-82.

Sharkawy, S.H.; Sharaf El Din, S.H. 1974. Hydrographic structure and circulation pattern of Abu Qir Bay near Alexandria, Egypt. Bull. Inst. of Oceanogr. and Fish., Cairo, vol. 4.

Tolbert, W.H. 1976. Unusual density layer in the Great Bitter Lake. (unpublished manuscript).

Ball, J. 1939. Contributions to the geography of Egypt. Cairo, Government Press, Survey and Mines Dept. 308p.

Balanc, J.J. 1968. Sedimentary geology of the Mediterranean Sea. Oceanogr. Mar. Biol., vol. 6, p. 377-454.

Butzer, K.W. 1960. On the Pleistocene shore lines of Arab's Gulf, Egypt. The Jour. of Geol., vol. 68, no. 6, p. 626-37.

D'Arrigo, A. 1936. Delta Del Nilo, Richerche sul regime dei litorali nel Mediterraneo. Ric. Var. Spiagge ital., vol. 14, p. 63-79.

Duplaix, S. 1958. Etude minéralogique des niveaux sableux des carottes prélevées sur le fond de la Méditerranée. Rep. Swed. Deep-Sea Exped., 1947-1948, vol. 8, no. 2, p. 137-66.

El-Awady, M.M. 1972. The physical and chemical properties of Alexandria Harbour waters relevant to fouling and anti-fouling paints . M. Sc. thesis, Cairo University (unpublished manuscript).

El-Boseily, A.M. 1965. Mechanical and mineralogical studies on the Egyptian black sand deposits on the Mediterranean coast of Rosetta Nile mouth". M. Sc. thesis, Alexandria University. (unpublished manuscript).

El-Sabarouti, M.A. 1973. Shore dynamics and morphological observations on the Nile Delta shores . Cand. thesis, Moscow University (unpublished manuscript).

El-Sayed, M. Kh. 1974. Littoral and shallow water deposits along the Mediterranean coast of Egypt, off Alexandria . M. Sc. thesis, Alexandria University.

El-Wakeel, S.K. 1964. Recent bottom sediments from the neighbourhood of Alexandria, Egypt. Mar. Geol., vol. 2, p. 137-46.

El-Wakeel, S.K. 1969. Foraminifera from bottom sediments of Lake Maryut and Lake Manzalah, Egypt . Bull. Inst. Oceanogr. Fish., Cairo, vol. 1, p. 429-48.

El-Wakeel, S.K. ; Wahby, S.D. 1970a. Texture and chemistry of Lake Maryut sediments. Arch. Hydrobiol., vol. 67, no. 3, p. 368-95.

El-Wakeel, S.K.; Wahby, S.D. 1970b. Bottom sediments of Lake Manzalah, Egypt. Jour. Sed. Petrol., 40/1, p. 480-96.

Emery, K.O.; Bentor. Y.K. 1960. The continental shelf of Israel. Bul. Geol. Surv. Israel, vol. 26, p. 25-41.

Emery, K.O.; George, C.J. 1963. The shores of Lebanon. The American University of Beirut, Miscellaneous papers in the Natural Sciences, no. 1, p. 1-10. (Contribution No. 1385 from Woods Hole Oceanographic Institution).

Emery, K.O.; Heezen, B.C.; Allan, T.D. 1966. Bathymetry of the Eastern Mediterranean Sea. Deep-Sea Res. Oceanogr. Abstr., vol. 13, p. 173-92.

Gilat, E. 1963. The macro-benthonic animal communities of Israel continental shelf in the Mediterranean. Rapp. Comm. Int. Mer Medit., Monaco, vol. XVII, p. 103-6.

Higazy, R.A.; Naguib, A.G. 1958. A study of Egyptian Monazite - bearing black sands. Proc. 2nd U.N. Int. Conf. on the peaceful uses of atomic energy. vol. 2, p. 568-662.

Hilmy, M.E . 1951. Beach sands of the Mediterranean coast of Egypt. J. Sed. Petr., vol. 21, no. 2, p. 199-220.

Malvina, B. 1966. The distribution of heavy minerals and their hydraulic equivalents in sediments of the Mediterranean continental shelf of Israel. J. Sed. Petr., vol. 36, no. 1, p. 126-74.

Mellis, O. 1954. Volcanic ash-horizons in deep-sea sediments from the Eastern Mediterranean. Deep-sea Res. Oceanogr. Abstr., vol. 2, p. 89-92.

Mohamed, M.A. 1968. Continental shelf sediments of the Mediterranean Sea North of the Delta in U.A.R. M. Sc. thesis, Alexandria University, (unpublished manuscript).

Mohamed, M.A. 1972. Study of Foraminifera in recent marine sediments on the Mediterranean continental shelf off the Nile Delta . Ph. D. thesis, Alexandria University. (unpublished manuscript).

Moussa, A.A. 1973. Study of bottom sediments of Abu Qir Bay . M. Sc. thesis, Alexandria University, (unpublished manuscript).

Nakhla, F.M. 1958. Mineralogy of the Egyptian black sands and its applications. J. Geol. Egypt, vol. 11, no. 1, p. 1-22.

Nawar, A.H. 1973. History of the formation of the Nile Delta in upper Pleistocene and Holocene. Cand. thesis, Moscow University. (unpublished manuscript).

Olanson, E. 1961. Studies of deep-sea cores. Rep. Swed. Deep-sea Exped., vol. 8, no. 4, p. 335-91.

Reiss, Z.; Klug, K.; Merling, P. 1961. Recent Foraminifera from Mediterranean and Red Sea coasts of Israel. Geol. Surv. Bull, Israel, no. 32, p. 388-95.

Said, R. 1958. Remarks on the geomorphology of the deltaic coastal plain between Rosetta and Port Said. Bull. Soc. Geogr. Egypt, vol. 31, p. 115-25.

Said, R.; Kamel, T. 1956. Recent littoral Foraminifera from the Egyptian Mediterranean coast. Bull. Inst. Egypte, vol. 37, no. 2, p. 341-75.

Shukri, N.M. 1950. The mineralogy of some Nile sediments. Q. J. Geol. Soc., London, vol. CV, part 4, p. 511-34.

Shukri, N.M.; Philip, G. 1956. The geology of the Mediterranean coast between Rosetta and Berdia. Part 1: Recent sediments. Mechanical analysis and mineral composition. Bull. Inst. Egypte, vol. 37, Fasc. 2, p. 377-93.

Soliman, S.M. 1964. Primary structures in a part of the Nile Delta and sand beach. In : Deltaic and shallow marine deposits. Amsterdam, Elsevier. p. 379-87.

APPENDIX V

A PROPOSED ACTION PLAN FOR THE EASTERN MEDITERRANEAN ECOSYSTEM

A Model to Evaluate the Impact of Human Activity and Technological Development on the Marine Environment

(Note : This proposal was formulated during the IBP/PM Symposium on the Eastern Mediterranean, held in Malta, from September 11-15, 1973)

The Eastern Mediterranean Sea is a unique part of the marine ecosystem, one that has been subjected to important geological changes beginning in the Tertiary and more recently to the effects of human activity which have reached a tremendous magnitude. For example, the cutting of the Suez Canal in 1869 and the building of the Aswan High Dam in 1965, both man-made, have led to large-scale ecological changes in the semi-isolated basin of the Eastern Mediterranean.

The Suez Canal, the Bosporus and the Strait of Sicily, are all pathways for the migration of marine organisms to and from the Eastern Mediterranean. The ecological implications of such migration are multiple and complex. The drastic reduction of freshwater and nutrient input resulting from the construction of the Aswan High Dam caused, in a short time span, drastic changes in the hydrographic picture and the productivity of the Eastern Mediterranean. The problem of pollution is increasing, adding to the complexity of evaluating the effects of human activity and technological development. Natural marine resources are changing as a result of the combination of reduced nutrient input, immigration through the Suez Canal and pollution.

Thus the Eastern Mediterranean represents a unique and unequaled model for evaluating the effects of human activity and technological development. Furthermore, the Eastern Mediterranean is a model for the present and the future. Unfortunately, large scale data are not available to allow accurate prediction of changes resulting from human activity and technological development. Nevertheless, the opportunity exists for an assessment of predicted changes and the degree of accuracy in their prediction. Certainly, the Eastern Mediterranean is a natural laboratory not only to model and monitor but to conduct studies for rational management of fishery resources and experiments in mariculture.

The scientific papers and discussions during the Symposium on the Eastern Mediterranean demonstrated the capability of the Eastern Mediterranean scientific community to analyze the magnitude of the problems. At the same time it was evident that there exists a lack of scientific data and of appropriate national and regional infrastructure and specialization by which one may evaluate on a multidisciplinary basis the total complexity of the Eastern Mediterranean Sea.

The participants of the Symposium on the Eastern Mediterranean recommend the following:

1. Research

The participants of the Symposium unanimously recommend that ecosystem modelling of the Eastern Mediterranean Sea, beginning at the Strait of Sicily, be initiated. Exploratory investigations are needed to determine basic oceanographic parameters, temporally and spatially, including the identification of indicator species and the mapping of pollution effluents. Data from exploratory studies would then be available for models of large-scale oceanographic processes. The total ecosystem model would include monitoring the effect of pollution, resources management, construction criteria and oceanic modelling.

It is recognized that all the recommended modelling components cannot be initiated immediately. Though such modelling represents the mechanism to achieve the ultimate objective, practical priorities are recommended which take into consideration the existing capabilities in the region. It is recommended that each country bordering the Eastern Mediterranean Sea agree:

a) to sample at regular intervals at one or several standard stations for basic physical and chemical parameters, including main pollutants, primary productivity and plankton biomass. Basic sampling design, standardization and intercalibration must be given priority;

b) to participate in making an inventory of marine organisms and setting up reference collections;

c) to study at regular intervals the changes in coastal and estuarine sedimentation;

d) to participate in the preparation of an inventory of past and existing data accumulated in marine research institutions.

2. Training and exchange of scientists.

The participants of the Symposium unanimously recommend:

a) that the infrastructure of existing marine programmes be strengthened;

b) that training courses be initiated to upgrade the scientific capability, utilizing the excellent Eastern Mediterranean centres already in existence and creating others;

c) that exchange of scientists and information between Eastern Mediterranean countries be facilitated through whatever means possible.

3. Co-ordination and administration.

The participants of the Symposium unanimously recommend that regular consultation be undertaken among marine scientists and marine science administrators from Eastern Mediterranean countries, with the co-operation of governmental, non-governmental and scientific insitutions and organizations having an active interest in marine research in the region, in order to identify scientific interest and marine resources.

Scientific research programmes on specific marine research topics proved to be of interest for the region, in particular for modelling of the marine ecosystem, and should be encouraged under the sponsorship of United Nations specialized agencies, such as UNESCO, FAO and UNEP and in close collaboration with the joint IOC/FAO (GFCM)/ICSEM Co-operative Investigations in the Mediterranean (CIM).

It is essential that the existing facilities and scientific manpower in the region be fully utilized. Duplication of efforts should be avoided through initiating and/or strengthening co-ordination and co-operation between countries and research institutions having scientific interests in the region.

4. Fundings

The participants of the Symposium unanimously agree that multiple funding from international governmental and non-governmental organizations as well as private institutions will be necessary to reach the ultimate objective.

Outline of Ecosystem Modelling for the Eastern Mediterranean Sea

I. Exploratory needs

A. Runoff inputs and budgets.
B. Flux input and output budgets of salt, nutrients, pollutants, etc., through the Strait of Sicily, Bosporus, Suez Canal and rivers.
C. Distribution of standard oceanographic parameters for baseline data including:
    1. Hydrography
    2. Current measurements
    3. Sediment regimes
    4. Primary productivity
    5. Taxonomy
D. Identification and agreement on indicator species.
E. Mapping of pollution effluents.

II. Process models

A. Convection and bottom water formation.
B. Large-and small-scale wind driven and thermohaline circulation.
C. Eutrophication:

1. Species change and diversity
2. Perturbation time scales
3. Effects on primary productivity
4. Uptake of pollutants by organisms
5. Nutrient kinetics

D. Dispersion studies under different flow scales.
E. Coastal geologic changes.
F. Contaminant uptake studies:

1. Petroleum
2. Heavy metals
3. Trace organic compounds

G. Air-sea interaction
H. Food chain studies.

III. Total and area ecosystem models

A. Monitoring of the influence of pollution.
B. Management of living resources.
C. Construction criteria for coastal facilities.
D. Oceanic modelling.

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