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The British Contribution to the I.B.P. Programme on Marine Productivity [and Discussion]

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The British contribution to the I.B.P. programme on marine productivity

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Since an efficient international network already existed to coordinate research in oceanic biology, the themes developed by the I.B.P. for the marine environment were related primarily to the productivity of coastal waters and the effects of Man's intervention on them.

In the United Kingdom much support had already been allocated to this area and a brief resumé of the U.K. programmes carried out on the main I.B.P. P.M. (Productivity of Marine Communities) themes will be given. I.B.P. played a significant rôle in drawing attention to the importance of marine productivity, encouraged University and other non-Government institutions to enter this field and promoted liaison between the various groups working on marine pollution. In the international context the U.K. contribution was appropriately directed towards providing manpower and equipment to support a joint project on the productivity of two beaches, one in the west of Scotland and the other in southern India. The results of this research are described in detail by Dr Steele. The arrangement had the advantage of flexibility and informality and offers perhaps the most successful way in which fundamental science can be encouraged in developing countries.

It would be appropriate at the outset for me to pay a tribute to the contribution which Mr R. S. Glover made to the P.M. section of the I.B.P. as Chairman of the British Committee and of the International Committee. But for his energy and enthusiasm at critical times, this part of the programme might not have got underway. The marine productivity section was faced with an initial dilemma. International cooperation in marine biology and physical oceanography had been well established at the start of the I.B.P., and was especially strong in those branches of the subject concerned with the high seas and the exploitation of resources, notably fisheries, in international waters. Fish stocks are necessarily shared between different nations and it has been recognized to be in the interest of all to pool the results of the rather expensive research which needs to be carried out on population dynamics, migrations and the general biology of commercially important fish. Organizations to promote such interchange have existed in the Atlantic area for many decades, while the F.A.O. has tried to extend such liaison to all other areas. Cooperation on the physics and chemistry of the sea is similarly organized between governments by the International Oceanographic Commission and between non-governmental organizations through the Special Committee of Oceanic Research.

Furthermore, the assessment of productivity throughout the ecosystem, which has been the mainspring of activities in the freshwater and terrestrial sections of I.B.P., has been a central theme in the ecology of open water marine and freshwater environments for the past forty or fifty years. Indeed it goes back to the days before there was a separation between 'marine biology', which is regarded as an academic subject, and 'fisheries', which is regarded as an applied subject and is largely supported by governments. The original unity of the subject, which followed from the recognition that fisheries were ultimately dependent on the lower trophic levels, led many years ago to intensive research into phytoplankton production and

what controlled it. This in turn made necessary an understanding of the seasonal changes in the physical variables and chemical nutrients of the water column. The ideas sown by James Johnson of Liverpool, together with the tremendously important research of the Plymouth Laboratory during the twenties and thirties with which the names of Lebour, Harvey, Atkins, Cooper and Russell are to be associated, and the initiatives of Professor Sir Alister Hardy's plankton group, which has a direct lineage traceable to the Institute of Marine Environmental Research, were all fully in line with the objectives of the I.B.P. and might indeed be regarded as originating the British contribution. It was clear, therefore, right at the beginning of the I.B.P. that the Marine Productivity section would need to take account of what international organizations already existed, and what kinds of programmes were already receiving adequate support. From this point of view the outlook was quite different from that of other sections. There were indeed those who considered that the marine section should have declared itself redundant and played no further part. In the event, other views prevailed, and it became evident that the existing organizations were largely concerned with the open sea and less concerned with shallow coastal waters and estuaries. However, the problems of coastal and estuarine areas are of extreme importance in all parts of the world: in the developing countries, estuaries and lagoons often represent regions of high potential in the production of prawns, edible molluscs, and fish, while in the industrial world they are often the receiving waters of large cities and therefore regions of high pollution risk.

The ecology of nearshore waters therefore became the focus of attention of the Marine Productivity section of the I.B.P. These regions comprise the brackish water and saline estuaries, salt marshes, coastal lagoons, coral reefs, mangroves, sandy and muddy shores, and their structure is much more complex than the open water ecosystems which have hitherto received the major part of governmental support. In resolving to concentrate attention on coastal and estuarine ecosystems, and considering particularly the effects of man's activities on their amenity and productivity, the I.B.P. has taken a step towards the reintegration of marine biology. The open water ecosystem, which has claimed more attention in the past, is concerned with the classical food chain of the upper and middle waters from microalgae through microcrustacea to fish. The study of shallower waters makes it necessary to pay much greater attention to what happens on the seabed and so to devote more resources to the study of benthic algae, herbivores, omnivores, scavengers and decomposers, which are likely to play a key role both in productivity and in the capacity to recycle organic wastes.

Subsequently the international programme has been divided into a number of special themes, one of them a comparison of marine ecosystems on a worldwide basis which more or less reflects the original programme. In addition, emphasis has been placed on mariculture and on the biology of certain organisms regarded as particularly important in coastal waters, namely mussels, mullet and marine mammals.

The I.B.P. section on Marine Productivity did not, however, include any genuine international project in the sense of groups of scientists from different countries working together in selected areas.

United Kingdom programme

In the United Kingdom there were already many national research programmes which fitted into the original context of I.B.P. and for which no further support was required. Indeed, only one Marine Productivity project was supported specifically from I.B.P. funds. This was a

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comparison of the productivity of temperate beaches in Scotland with that of tropical beaches in India, and was carried out jointly between the D.A.F.S. Laboratory in Aberdeen and the Indian National Laboratory at Ernakulum. It eventually drew into its ambit research workers from the Dunstaffnage Laboratory and from Stirling University. This funding was extremely useful in making a link possible between two groups of workers in parallel institutions in Scotland and in India and proved to be a highly successful enterprise. The common language, the historical ties between India and the U.K., and the absence of excessive bureaucratic formalities, allowed a free flow of ideas and a concentration on scientific rather than logistic problems. It clearly fitted into the I.B.P. framework and spirit. The detailed results of this project will be described separately by Dr Steele.

The remaining British contributions were originally chosen because they appeared to conform with the area of study selected by the I.B.P., but it must be admitted that because of the wide range of such activities in the United Kingdom, the separation of a distinct I.B.P. series of projects was somewhat arbitrary and became increasingly so. Indeed, many more projects might have been included, especially some which began after the I.B.P. had been set up, while some of those which were included eventually faded out. In this review of the British contribution I shall therefore concentrate only on those programmes which appear to me to have made important contributions to the main, or to one of the subsidiary, themes of the I.B.P., or which have been clearly influenced by the existence of the programme.

Marine productivity studies

In addition to the U.K.–India project on the productivity of sandy beaches, three further extensive studies of nearshore productivity have made good progress. The Department of Zoology at Aberdeen, using its field station at Culterty as a base, has instituted a series of detailed projects on the main animal components of the food web of the Ythan Estuary. They comprise the invertebrate prey of birds and fishes – notably the polychaete *Nereis*, the bivalves *Macoma* and *Mytilus* and the gastropod *Hydrobia* – together with the food sources – detritus, benthic microflora and *Enteromorpha* – and of the main predators, the Eider duck, Shellduck, and Oystercatchers among birds, and the Flounder and Sand Gobey among fish. It will be a big task to sift, analyse and consolidate the wealth of information available, much of which is still unpublished, but when completed it should provide a very detailed picture of the energy flow in an almost unpolluted estuary. It will thus form an interesting comparison with the much larger and heavily polluted estuary of the Bristol Channel, which is currently being studied by I.M.E.R. in collaboration with several universities.

The second productivity study is concerned with the role of the macro-algae in the context of the productivity of marine and brackish sea lochs. These lochs are likely to become increasingly important as centres of mariculture in the British Isles. The work at present is centred at the Scottish Marine Biological Association's Laboratory at Dunstaffnage, Argyll, where the ecology and growth of the larger brown algae are being studied, while a group working under Dr C. S. Johnson at the Heriot-Watt University, Edinburgh, is carrying out physiological, biochemical and structural studies to complement the field work.

The above studies represent a substantial contribution to the theme of 'Marine production in different climatic zones'. The third United Kingdom study, falling directly into the field of Marine Productivity, concerns the important herbivore *Calanus*. It is the dominant link in the

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food chain of the open water ecosystem between the microalgae and certain pelagic fish. The study of *Calanus* owes much to the classical work of two British marine biologists, Marshall & Orr, who believed that *Calanus* was an efficient transformer of energy from the first to the second trophic level. During the past five years at Plymouth Dr Corner has been working on two problems which are fundamental to the understanding of the nutrition of *Calanus*. The first concerns the efficiency with which algal food is utilized. It has been suggested, contrary to Marshall & Orr's views, that during the spring when the marine microalgal flora was especially abundant, *Calanus* took in more food than it required and therefore utilized only a small proportion of its intake. A somewhat similar suggestion was that *Calanus* wantonly destroyed many of the algal cells which it did not require to ingest. Neither of these ideas have found any support in Corner's work. On the contrary, by careful biochemical studies under controlled conditions he has shown that *Calanus* has both a high assimilation and a high growth efficiency, and thus has restored our confidence in its role in the marine ecosystem. The second problem concerns the nutrition of *Calanus* during the winter when algal food is scarce. It appears that at this season *Calanus* may supplement a diet of detritus with animal food.

Pollution research

Probably the British I.B.P. (P.M.) Committee exercised its greatest catalytic influence in studies of coastal pollution. In 1968 Professor R. B. Clarke initiated a cooperative programme on Coastal Pollution in the North East of Britain by enlisting various workers in the Universities of Leeds, Durham and Newcastle. The group was subsequently widened by the inclusion of others working further afield, notably members of Liverpool University, of the Ministry of Agriculture, Fisheries and Food Laboratory at Burnham and of the I.C.I. Industrial Pollution Laboratory at Brixham. Although this group probably became too broad to form a really cohesive programme and the work of the non-university personnel remained relatively uncoordinated with the rest, the provision of travelling funds for research discussions was especially useful to the university members, since university staff are notoriously ill-provided in this respect.

This joint programme can be divided into three main areas of work.

(*a*) *Seaweeds as pollution indicators*

The first problem arose from the proposed use of the large brown seaweeds as pollution indicators. Initially the Durham group found a correlation between pollution and growth rate *in situ*. Subsequent investigations at Liverpool University on the growth rates of sporelings *in vitro*, using known concentrations of pollutants, under varying light intensities, and with waters of different origin did not entirely agree with the rather simple conclusions from field observations. They indicated that the effects of the various dissolved substances and of silt could not readily be disentangled.

(*b*) *The kelp microcosm*

The second investigation was the use of kelp holdfasts as a 'sample ecosystem' from which the biological condition of the environment might be judged. The holdfast of *Laminaria hyperborea* is a relatively small, discrete structure which can be sampled by diving, even in turbid water, and examined subsequently in the laboratory. The holdfast fauna is very rich in species (220 have been recorded from one site at Robin Hoods Bay) and so can be used to

study changes in faunal composition. Dr P. G. Moore has used this method extensively along the northeast coast and explored a number of statistical procedures for classifying and ordinating the associations in relation to water quality

(*c*) *Interstitial ecosystems*

The third series of investigations, prompted by the threat of a large scale injection of industrial clay waste, was a study of the effect of pollutants on the interstitial fauna of sands. MacIntyre had shown, by the use of sand columns as artificial beaches, that sand bacteria could utilize dissolved materials and thus provide energy for the fascinating assembly of organisms which live in the labyrinthine spaces between the sand grains. The system occupies in nature the role of a sewage purification plant. John Gray developed an 'artificial ecosystem' consisting of a bacterial culture of *Pseudomonas* supporting a population of the bactivorous ciliate *Cristigera*. The system works rather like a chemostat, and the population changes are extremely sensitive to the presence of small concentrations of pollutants and mixtures of pollutants. The method offered a very promising approach for comparing and assessing the effect of nearshore water quality on a simplified ecosystem.

(*d*) *Oil pollution*

The United Kingdom programme also included a number of pollution studies which need not be enumerated here, but which were concerned with widely separated coastal sites, or aimed at specific problems. The Institute of Petroleum and the Field Studies Council have supported research at the Oil Pollution Research Unit, Orielton, in Milford Haven, on the effects of oil pollution and cleansing operations on the intertidal fauna, and incidentally have carried out much valuable basic intertidal biology. The first few years of research dealt largely with the effects of oil pollution on rocky shores, and was published as a book by the Institute of Petroleum. A second book, rather more broadly based, is to be published later.

Special themes

The special themes introduced after the United Kingdom's programme had been planned would have led to the inclusion of several additional groups as a part of the I.B.P. For example, the proposed programme on marine mammals would have included the Seal Research Unit of I.M.E.R., while Dr Brian Bayne's extensive programme on the effect of environmental stress on mussels, which began at Leicester University and is continuing also under I.M.E.R., together with many other United Kingdom studies on *Mytilus*, could well have been included at the outset. Dr Bayne's work includes not only the study of the productivity of *Mytilus* as an important component of the coastal ecosystem with considerable potential in mariculture, his investigations on the changes in its biochemical constituents also provide the possibility of using the animal for integrating the level of 'environmental stress'. It therefore combines the themes of marine production, mariculture and pollution. Fortunately Dr Bayne will be editing the International Synthesis Volume on *Mytilus* and therefore the extensive United Kingdom work on this animal will be fully reported.

Such projects which, in retrospect, could well have been included among the special themes of the marine productivity programme, illustrate that the breadth of the marine section of the I.B.P. has made it impossible to divide off any one set of projects from cognate work proceeding

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simultaneously. Therefore any attempt to synthesize the results on the basis of the I.B.P. programme alone would be most unsatisfactory. No doubt this is true of the work in many other countries as well as the United Kingdom. It has therefore been decided that the Editors of the Synthesis Volumes will be free to draw on all relevant papers.

The value of the work of the Marine Productivity section of the I.B.P.

Since the advent of the I.B.P. did not stimulate any appreciable injection of funds into the United Kingdom's effort in marine science, it would be remarkable if any spectacular increase in research output had been achieved. Whatever changes were brought about could therefore only be made at the expense of work done in some other field. Indeed, a swing of emphasis brought about by mere exhortation would not necessarily be beneficial. The benefits of the I.B.P. should therefore be sought in improved communications between individuals and greater interaction between disciplines.

No doubt the United Kingdom Marine Productivity Committee was useful in bringing together British scientists, especially those studying pollution problems, but the joint United Kingdom–India programme on the productivity of sandy beaches was a more impressive piece of cooperation, and one with an international content. There are many operations of this kind now taking place in the world. The association of two or more national groups within a flexible programme appeals to me as one of the best ways of promoting science in developing countries and by far the most effective form of training.

A further achievement in communication in a somewhat wider context was the production of the Handbook on Benthos Methods. Early in its deliberations, the International Committee for Marine Productivity saw the need for a booklet for marine biologists to assist them in the measurement of the productivity of bivalve or prawn fisheries, or in conducting general surveys of the benthos, for example in relation to pollution. This handbook would therefore need to include an account of the various operations that are required, with advice on the simpler methods and references to the more refined techniques. As with other handbooks, it was clearly impossible for the Committee itself to prepare it in detail. Instead an international workshop of experts was held at Arcachon, France, and on the basis of the views expressed there, the United Kingdom Marine Productivity group prepared and published the handbook under the editorship of Dr N. Holme and Dr A. D. MacIntyre.

Another byproduct of the United Kingdom's Marine Productivity Committee was the *Pollution Bulletin*. It was started in June 1968 by Professor R. B. Clark as an informal newsletter with a restricted circulation within the United Kingdom. The articles proved to be in great demand, and its commercial publication as a bulletin for the whole of the Marine Productivity programme began in June 1970. The publication was recently transferred from Macmillan Journals to Pergamon Press and is now in its sixth volume. There is no doubt that it will outlive the I.B.P. as an international bulletin.

The second benefit I see arising from I.B.P. is a greater interaction between disciplines. The broad coverage of the organization has enabled botanists, zoologists and microbiologists to associate in the comparison of a great variety of habitats, aquatic and terrestrial. It has, I believe, already played a part in the generation of new ideas, though I suspect that after the Synthesis Volumes have made their impact there will be a certain amount of criticism of the

I.B.P. because of the very limitations of the energy flow concept. Thus in a dialectical fashion, the I.B.P. will have helped towards a fuller appreciation of how ecosystems work.

Discussion

G. E. Fogg, F.R.S. (*The Marine Science Laboratories, Menai Bridge, Anglesey, Gwynedd*)

A special section of the I.B.P. was set up to deal with the conservation of terrestrial communities but, as far as I know, no consideration was given to conservation in the sea, although this would seem to be just as urgent. Would Professor Crisp care to comment on this?

D. J. Crisp, F.R.S.

While the Marine Productivity section of the I.B.P. never addressed itself specifically to the problem of conservation, in the sense of coastal reserves, marine parks or legislation against collecting specific organisms, in the broader sense of conservation the emphasis which it placed on the prevention and abatement of pollution was a significant contribution. There were, of course, the well established conservation arrangements in many parts of the world for commercially exploitable species, but these lay outside I.B.P.s own priorities.

Conservation measures directed towards the preservation of parts of the coast will meet with some difficulty. In the United Kingdom especially the coast is owned by the Crown and regarded as public property; to restrict access will require unpopular political decisions unless the public can be convinced of its necessity. Controlling certain operations also will create difficult problems. Furthermore, most marine organisms reproduce by widely disseminated larvae so that a small population in an isolated area might not be able to maintain itself. Up to the present time the British intertidal zone, unlike that of some Latin countries, has not been heavily exploited, and therefore legislation has not appeared to be necessary.

I believe the situation has now changed. Much greater public use is being made of the shore and of the sublittoral; collecting by Scuba divers, and particularly spear-fishing, is increasing in popularity, while large scale exploitation of intertidal plants and invertebrates is now in progress. There are great unseen scars on the seabed made by gravel-extracting firms. Abroad, the trade in attractive shells and tropical fish together with extensive land reclamation schemes is being widely criticized by conservationists.

The whole problem of the conservation of the marine environment, and not only its fishery potential, is now being reviewed by N.E.R.C. and N.C.C. so that we hope action can be taken in time as far as the British coast is concerned. It must be admitted, however, that some of the above operations will prove extremely difficult to police.

E. B. Worthington

Dr Worthington commented on the rapid development in conservation of marine coastal areas during the past few years. The P.M. project on 'Aqua Marina' had never developed as such because, during the period of I.B.P., I.U.C.N. had taken up the cudgels of marine conservation with vigour. A number of countries – for example Japan and Kenya – had already established marine national parks, especially in areas of coral reefs. There seemed to be good prospects of many other areas, especially in the tropics, obtaining similar conservation status before long. I.U.C.N. have an active advisory committee on the subject chaired by Carlton Ray.

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