REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

Co-operation for environmental protection in the Pacific

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EDITOR'S PREFACE

The Regional Seas Programme was initiated by the United Nations Environment Programme (UNEP) in 1974 in response to the selection of the oceans as a priority area by the UNEP Governing Council. It is a global programme implemented through regional components under the guidance of the Oceans and Coastal Areas Programme Activity Centre at UNEP headquarters in Nairobi.

Each regional action plan is formulated by the Governments concerned to respond to the needs of the region for a comprehensive approach to controlling both the consequences and the causes of environmental degradation through the management of marine and coastal areas. Action-oriented programme activities are generally supported by regional legal agreements.

The oceans are an element uniting the countries of a region in the management of a shared resource. Many marine environmental problems require a common or at least co-ordinated approach by all the governments concerned. The success of the ten Regional Seas action plans involving over 120 coastal states proves the effectiveness of this approach. Nevertheless inter-regional co-operation is important to share experience and to assure the compatibility of the different regional components.

The three Regional Seas Action Plans in the Pacific illustrate the different origins and approaches of regional efforts to manage the marine and coastal environment. The South Pacific Regional Environment Programme (SPREP) had its roots in the regional environmental activities of the South Pacific Commission (SPC) starting in 1974, before becoming a joint programme with the South Pacific Bureau for Economic Co-operation (SPEC), and then being adopted as a UNEP Regional Seas area in 1979. Its action plan [1] was approved by governments at the Rarotonga Conference in 1982, and a regional convention was signed in 1986. SPREP covers both the terrestrial and marine environments, and includes both scientific and educational components.

In the South-East Pacific, the Member States of the Permanent Commission for the South Pacific (CPPS) requested UNEP to assist in the development of an action plan for that region, starting with an international workshop in 1978 and leading to the adoption of both the action plan and a regional convention at Lima in 1981 [2]. The CPPS provides the secretariat for the action plan, which gives major emphasis to the study and control of marine pollution.

The East Asian Seas action plan was developed under UNEP supervision for the ASEAN member countries, which adopted it in 1981 [3]. Its activities are approved by annual meetings of the Coordinating Body for the Seas of East Asia (COBSEA), and UNEP continues to serve as the secretariat, with different projects implemented by government agencies or organizations on behalf of the countries of the region. A regional trust fund contributes to project support, but there is no regional convention or co-ordinating unit at present.

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[1] SPC/SPEC/ESCAP/UNEP. 1983. Action Plan for managing the natural resources and environment of the South Pacific region. UNEP Regional Seas Reports and Studies No. 29. UNEP, 1983.

[2] CPPS/UNEP. 1983. Action Plan for the protection of the marine environment and coastal areas of the South-East Pacific. UNEP Regional Seas Reports and Studies No. 20. UNEP, 1983.

[3] UNEP. 1983. Action Plan for the protection and development of the marine and coastal areas of the East Asian region. UNEP Regional Seas Reports and Studies No. 24. UNEP, 1983.

Since these three action plans all concern the same ocean, it is logical that UNEP should make a special effort to encourage inter-regional co-operation. The first meeting to bring together scientists from the three programmes for a joint review of their progress was held at the 15th Pacific Science Congress in Dunedin, New Zealand in 1983, and the results were published by UNEP in **Environment and Resources in the Pacific**, UNEP Regional Seas Reports and Studies No. 69 (1985). The papers in this volume were presented at a similar UNEP-sponsored symposium, "Regional Co-operation on Environmental Protection of the Marine and Coastal Areas of the Pacific", organized in association with the XVI Pacific Science Congress in Seoul, Korea on 25-26 August 1987, and hosted by Hanyang University. Scientists actively involved in the implementation of the action plans in the Pacific were invited to share their results, to develop contacts with their colleagues in other regions, and to suggest further development of inter-regional activities and co-ordination. A section concerning environmental protection in the North-West Pacific was added to allow scientists from countries in that region to review their marine and coastal research and monitoring activities and to consider the advantages of regional co-operation on the Regional Seas model.

As organizer of the symposium on behalf of UNEP, I should like to acknowledge the co-operation and assistance of the Pacific Science Association, the Organizing Committee for the XVI Pacific Science Congress, Hanyang University, and in particular Professor Tae Hoon Yoon, the local organizer, in facilitating the arrangements for the meeting. Thanks are also due to all the authors for their co-operation in helping to bring these proceedings out quickly.

Arthur Lyon Dahl

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SCIENCE, SCIENTISTS AND DEVELOPMENT

(Plenary Address at the XVI Pacific Science Congress)

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A hundred and fifty years ago Mary Shelley sat down to write a book. She called it "The New Prometheus", recalling the Greek legend in which man receives fire from heaven, but is then destroyed by his discovery. In her book a well-meaning scientist, a certain Dr. Frankenstein, creates a new human being. Frankenstein's monster is science at its worst: life without soul, knowledge without purpose, skill without wisdom.

This is the negative view of human nature. This is the view that assumes that science is the rope with which man will hang himself, that knowledge is the beginning of destruction.

It is an old view. The Bible, the Koran and the Torah begin with the story of man and woman in the garden of innocence. There they are tempted by knowledge, and after that time they are doomed to sin and to death. From Adam to Orwell the idea has had a powerful grip on the imagination: we have the ability to create but not to control. We are the sorcerer's apprentice, too clever for our own good.

There is a positive view. Anthropologist Jacob Bronowski once declared that knowledge is man's destiny. Knowledge, in this view, is an end in its own right, the goal to which man is ascending. And from knowledge comes a new human being, a human being governed by understanding and freed from material want.

The twentieth century has given both schools of thought ample room to express themselves.

The optimists point to incredible progress. More people are alive. More people live longer. More people eat more. More people know more than ever before. Even the mushroom cloud has a silver lining. The damocles sword of nuclear arms has brought a degree of stability in a century of conflict and doubt. A generation has grown up and is growing old without ever having seen the great powers at war. Science has given us more than we would dare to gamble in war.

Pessimists, however, point to the grim side. More people are hungry now than at almost any time in history. More species have been destroyed in the twentieth century than at any time since the end of the dinosaurs. The nuclear peace is a chimera. Deterrence is a fantasy. We are like the man who has jumped off the Empire State Building. We have plunged to the height of the 50th floor and we feel great: nice breeze, good view, no reason to worry.

There is merit in both cases. Both cases, I would guess, are somewhat exaggerated, but both points of view stress an argument that is more debated outside of the scientific community than inside it. That is the question of how we use science.

Are we using science responsibly?

Can we do more to bend the resources of science to the needs of society?

These are not new issues, but they take on a new urgency in the context of the late 20th century environment, especially in the Pacific.

People always say that the Pacific basin will become the hub of economic growth in the next century. Economic development is definitely accelerating in many of the countries of the region. Whether that development will benefit the people who need it most, and whether that development can be maintained for future generations, will depend on sustainable development. If sustainable development is the framework for progress, then we have reason for optimism. It is up to scientists to show the sponsors of science that sustainable development can work, does work, must work.

I am aware that this is much easier said than done. I am aware it entails major adjustments in thinking, action, and above all, styles of life.

For sure, this also means an important change in the way scientists see their work. Truth has traditionally been the ethical focus for scientific enquiry. To that we must now add a concern for social, economic and even spiritual development.

Scientists of the old guard will argue that we are taking science out of the world of pure reason and into the world of politics and economics. But that has already happened. We are already being shaped by science as never before. The question now is simply whether we control science or whether science will control us. As the guardians of technical knowledge, scientists can be doing more to direct their tools and to shape the future.

Scientists have, in the large majority of cases, seen themselves as being at the mercy of grant-givers. That is partially true. It is easier to get grants for military research or industrial research than for desert research or tropical forest programmes. That is largely beyond the control of scientists. Scientists can - and often do - claim that it is not their fault if science is misused by politicians and economists. The easy line: Don't blame me, I just work here.

The fact of the matter, however, is that there is a large margin of error in this assumption. It is based on the consideration that science is above the world of human affairs.

Here I am not theorizing, I am speaking from experience, three decades of experience in the natural sciences.

Scientists are an important and potentially influential group of people. But too often they stay above the fray. And by staying above the fray they become a party to the abuse of science.

Scientists run the risk of becoming cynical. At the end of his life someone asked Albert Einstein what he thought would be the ultimate weapon of World War Three. He said he didn't know, but that he thought the ultimate weapon of World War Four would be the club.

I say that it is scientists' job to make sure that is not the case.

When, from time to time, scientists do climb down from the ivory tower, they can surprise even themselves.

One recent example is very close to my heart as the head of the U. N. Environment Programme. That is the example of ozone.

Almost 15 years ago two American scientists postulated that stratospheric ozone was modified by the emission of chlorofluorocarbons, or CFCs, the chemicals used in aerosol solvents, propellants and refrigerators.

It was an interesting exercise. For the next decade and more scientists debated the effects of a CFC build-up. By the early 1980s scientists were in basic agreement that CFCs did modify stratospheric ozone, and that even a relatively minor depletion could have a major effect on environment and human health, particularly on the incidence of skin cancer. The scientists had said their piece, and had been largely ignored.

The mid-1980s widened the argument. Scientists agreed that chemicals known as halons also had the capacity to disrupt the ozone layer. And CFCs turned out to be linked to another issue of environmental significance: the greenhouse effect. Still not much happened.

Some time ago UNEP decided that the case against CFCs was strong enough - and that the risk was great enough - that the international community would be wise to restrict CFC emissions.

The government of the United States had already banned the use of CFCs as aerosols, but other, primarily industrial, uses were increasing sharply. Other governments, however, were slow to act. They had CFC industries to protect. Why jeopardize jobs and economy at a time of high unemployment and slow economic growth? Why deprive those long deprived of decent refrigeration - especially in the developing countries?

UNEP has great sympathy with these arguments. We are in favour of an agreement that would promote the development of non-ozone-depleting substitutes. We are in favour of phased regulations that would allow substitute plants to come on-stream before the closure of old plants. We are in favour of allowing low-consumption countries, basically developing countries, a grace period to adjust. But we are not willing to turn a blind eye to the fact that millions of lives are being put at risk.

Those who perceived themselves as being threatened by CFC regulation looked at the debate within the scientific community (the normal academic debate that we see all the time), and said that the scientists disagreed. If scientists had not yet agreed, why jump to conclusions?

So the debate dragged on, and eventually the scientific fraternity decided to put its foot down. Earlier this year a group of the world's major ozone modelers came together at Wurzburg in the Federal Republic of Germany. They compared their models using various different scenarios of CFC modification. Once and for all they showed that there was no meaningful difference of opinion within their community. All of them believed that it would be irrational to let ozone-depleting emissions go unchecked.

The press took their views to the public. UNEP convened a meeting of technical and legal experts on the ozone layer. There the scientific community repeated its stance, and presented - in terms meaningful to politicians - the case against CFCs.

What has been the result? The result has been that we are now on the brink of an international agreement to freeze and reduce the emission of ozone-depleting chemicals. Thanks largely to the intervention of the scientific community, we can look forward to an ozone protocol before the end of next month.

If it can be done once, it can be done a hundred times. If it can be done in one field, it can be done in other fields.

Indeed, there are signs, here and there, that scientists are bending their efforts towards sustainable development. A few of these should be singled out as models for the rest of us. UNEP, for instance, congratulates the Scientific Committee on Problems of the Environment for its research into the nature of nuclear winter.

UNEP congratulates Prime Computers which has helped to set up the Global Resource Information Database that collects, digitizes and distributes geographical information fo planners. We congratulate the young men and women from universities and research institute who have dedicated themselves to setting up that system.

We congratulate the scientists, governments and industries that are supporting a ne global code on the safe use of chemicals.

We are impressed that scientists at this congress have taken a new interest in th regional marine pollution symposium. Marine pollution conventions have been an importar plank in the platform of sustainable development. We are relieved to see scientists puttir their weight behind those efforts.

We congratulate these people for reminding us that the burden of science is not simp an intellectual one, it is also a moral one. With knowledge must come responsibility.

At a time when the Pacific basin is being shaped by economic growth and scientif advance, scientists have a responsibility to ask themselves about the effect of their work. their work is a frivolous or malign use of their talents, then it is their job to say so.

I will finish by recalling the story of Galileo. About 400 years ago Galileo let it be known that he thought the world was round and that the earth revolved around the sun. It was a dangerous belief in 16th century Italy. The Pope's inquisitors told him that he could die for a heresy like that. He would either have to recant or face trial. For Galileo the choice was easy. He would recant; after all, whatever he said the world would be no rounder, the earth's orbit no different. Galileo could honestly say that his work made almost no difference to the world of human affairs. We have inherited some measure of Galileo's ethereal view of science, but we have not inherited a world in which science doesn't matter. We have inherited a world that cannot even feed itself without the help of advanced science.

Science is closer to our lives now than it was in Galileo's day. The work of scientists shapes not only the way we think, but the way we live, and indeed, whether we live at all. Science must play a role in controlling what it creates. Scientists must have a say in the fate of their brain children. You can help correct the path. Look at your gathering today. You are coming from every corner of the globe. A message that goes to the world from this and similar gatherings will be listened to. As a group, the scientific community has weight and influence. Use that to ensure a better life for everybody, to ensure that science is used to build and not to destroy, to ensure that the interdependence between nations is a fact not a slogan, and finally to prove that we scientists understand and respect and are determined to fulfill our responsibility towards the generations to come.

REGIONAL CO-OPERATION: STILL AT SEA

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There is a new word in use in the international community. The word is "mego". It stands - so they say - for "my eyes glaze over". It refers to issues of indisputable importance, which are so tired, so remote, so obviously beyond the reach of reality that one ignores them, one's eyes glaze over them.

Peace on earth is a mego. The brotherhood of mankind is a mego. Regional co-operation, I am afraid, may also become a mego. It was much praised, much called for, but when we begin to look at what people are doing about it, we find little.

It is therefore a great pleasure for me to open this symposium on regional co-operation and the marine and coastal environment of the Pacific. Here we have an example of regional co-operation actually working. Here we have an example of nations sitting down together and talking about the management of shared resources, and the solutions to shared problems.

There are three sub-regions that will be discussed at this symposium: the East Asian Seas; the South-East Pacific; and the South Pacific. Between them the three areas cover much of the Pacific rim, and a sizeable percentage of the earth's marine surface.

The scope of the agreements, and the achievements they have to their credit, are a tremendous vindication of regional co-operation. One region, however, is noticeable by its absence. In a series of agreements that covers so much of the region, it is unfortunate that so far the North-West Pacific has not been drawn into the fold of regional environmental co-operation.

Colleagues tend to point out that substantial political divisions separate China, Japan, the Soviet Union and the two halves of the Korean peninsula. Frankly, I don't see that as a great obstacle.

UNEP has shown before that very different, and very antagonistic, nations can be brought together by the magnet of common interest. The very first regional marine agreement UNEP sponsored brought together Israel and the Arab states; brought together Greece and Turkey; brought together East and West; brought together North and South.

In fact, I would say that the environment is an ideal meeting place for nations - which although antagonistic - have recognized that they have nothing to gain from cutting off their noses to spite their faces. Indeed, once they start talking about shared interests, these nations often find that they have more in common than they ever believed.

An interesting example of this cropped up not long ago in Europe. The nations of Eastern and Western Europe sat down at the negotiating table and worked out a treaty on acid rain. The treaty called for a 30% cut in sulphur dioxide emissions. None of them had anything to gain from acid rain, so they signed. At the ministerial signing meeting I said that it was an impressive start, and that now they needed a similar agreement to cover oxides of nitrogen. Much to everyone's satisfaction that agreement, too, is well on the way to becoming law.

The basic message is that no single nation can handle these international environmental issues in isolation. This is particularly true in this region with its heavily populated seaboard, with its massive and still growing coastal industry, with its world-wide web of trade, and with its enormous fishing fleets and merchant marine. This region is ripe for co-operation. Everyone can be a winner.

This is one of the reasons why delegates to the Pacific Science Congress will be following this symposium so closely. This region will be the hub of economic growth, at least for the next generation. It will be interesting to see whether this region will learn from the experience of Europe and the North Atlantic states. It will be interesting to see whether growth can be extended indefinitely through sustainable development.

This symposium is indicative that sustainable development is indeed the framework for sustained economic growth in the region.

A number of activities seem to highlight that possibility. The State of the Marine Environment Report is one such study. Another is the study initiated by UNEP on the socio-economic and ecological effects of climate change on the island states of the Pacific.

I have just touched on areas where we have an impressive array of experts in the meeting. Perhaps the highest compliment I can pay those experts is to pass the floor to them, and to declare this symposium officially open.

THE UNEP-SPONSORED REGIONAL SEAS PROGRAMME

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ABSTRACT

The protection of the marine environment goes beyond pollution control. Most marine environmental problems originate in land-based activities which exert a decisive influence on the quality of the marine environment. Consequently UNEP pursues an interdisciplinary and integrated approach to problems causing deterioration of the coastal and marine environment, harm to living resources, destruction of ecosystems and amenities, and hazards to human health.

Man's impact on the marine environment is global in nature although it is most prominent in coastal and semi-enclosed waters bordering highly populated and industrialized zones. A few marine environmental problems are truly global, such as the impact of expected global warming and sea-level rise, the build-up of persistent contaminants due to long-range atmospheric and oceanic transport, and damage to widespread marine and coastal ecosystems from commercial exploitation or destruction of habitat, but most of them are region- and site-specific. The UNEP Regional Seas Programme provides a globally co-ordinated regional approach to their solution.

This Programme today covers ten regions and involves more than 120 countries. It is based on specific regional action plans formally adopted by the governments and supported in most cases by regional conventions providing the legal framework for the action plans. The three regional action plans in the Pacific region illustrate UNEP's experience with the Regional Seas Programme.

Each action plan includes assessment, management and supporting measures which are interdependent, specific to the region concerned, and supported by the political agreement of the Governments. They are executed primarily by national institutions and experts from the region.

The United Nations Conference on the Human Environment, which met in mid-1972 in Stockholm, was the first major meeting where the Government representatives of most States met to discuss their approach to the protection of the environment. The meeting was not easy. Many of the developing countries had yet to be convinced that the environment is our common global heritage and that the problems of pollution are not restricted to the industrialized world. At the end of the meeting a consensus was reached on a "masterplan" for the protection of the world's environment which linked environmental assessment, environmental management and supporting measures as basic and inseparable elements of a global strategy.

The oceans have no real borders and therefore the protection of the marine environment was easily identified in Stockholm as an obvious target for international co-operation.

Since 1972, our understanding of the problems facing the marine environment has increased considerably. The fears of imminent "death" of certain marine regions proved to be baseless but the results of sober analysis of the situation revealed that there is no time for complacency.

Today we are aware that man's impact on the marine environment is global in nature, although it is most prominent in coastal and semi-enclosed waters bordering highly populated and industrialized zones. Only a few marine environmental problems are truly global, such as the impact of expected global warming and sea-level rise, the build-up of persistent contaminants due to long-range atmospheric and oceanic transport, and damage to widespread marine and coastal ecosystems from commercial exploitation or destruction of habitat. Most of the problems are region- and site-specific.

This notion was basic in UNEP's approach to the problem. Instead of developing a glamorous "global" programme, UNEP opted for regional programmes, designed to solve the specific problems of the most endangered parts of the oceans: the coastal and semi-enclosed seas. The initial hope was that by covering the globe with a mosaic of regional programmes and by suitable co-ordination between such regional programmes, ultimately a global approach would be achieved.

The approach, today known as UNEP's Regional Seas Programme, proved to be valid if its success is measured with the achieved results in the last fourteen years. The Programme today covers ten regions and involves more than 120 countries. It is based on specific regional action plans formally adopted by the governments and supported, in most cases, by regional conventions providing the legal framework for the action plans.

Each action plan is different, responding to the specific perceived and actual threats to the region. The action plans go beyond control of marine pollution. They recognize that most marine environmental problems originate in land-based activities which exert the most decisive influence on the quality of the marine environment. Consequently, the action plans pursue an interdisciplinary and integrated approach to the solution of problems causing deterioration of the coastal and marine environment, harm to resources, destruction of ecosystems and amenities, and hazards to human health.

Each of the action plans is based on the three principles adopted in Stockholm: assessment, management and supporting measures.

<u>Assessment</u> involves identification of the sources of pollution, the nature and amount of pollutants entering the sea, and the fate and effect of these pollutants on the marine environment. National laboratories, supported by specialized international organizations, are organized in pollution monitoring and research networks, working according to a plan agreed in advance. Assessment also involves identification of activities and processes leading to the degradation of the coastal and marine environment, such as those resulting from ill-conceived coastal development schemes. Social and economic factors, including national legislation, that may influence, or may be influenced by environmental degradation are also studied because without their full understanding no meaningful action can be taken.

Assessment is not a goal in itself. It is intended to provide national policy-makers, experts and the public at large with the information and recommendations needed to improve environmentally sound <u>management</u> of their natural resources in a more effective and sustainable manner. Such management means improved control of industrial, agricultural and domestic wastes; development of contingency plans for dealing with accidents harmful to the marine and coastal environment, and application of such plans in cases of emergency; sustainable use, without over-exploitation, of fisheries resources, mangroves, coral reefs, lagoons and estuaries; and training in specific techniques and skills needed to apply management measures.

The <u>supporting measures</u> do not include financial support only. Although UNEP usually provides the initial funds for the development of the action plans, for training, for setting up research and monitoring networks, and for some equipment needed for their work, UNEP's financial support is gradually decreasing and the costs are increasingly shared by the governments participating in the action plans. The establishment of specific trust funds proved to be essential for the financial stability of the action plans. Another important supporting measure is a legally binding regional agreement which provides a legal framework for the action plan and ensures that national legislation is harmonized on a regional level.

Each regional action plan is serviced by its own secretariat operating under the authority of periodic, annual or biennial meetings of Governments concerned. Such meetings have the ultimate authority over the action plan; they review its progress and decide about

In the Pacific region UNEP services the East Asian Seas action plan directly while in the South Pacific and the South-East Pacific regions it supports the action plans through their own secretariats: the South Pacific Commission in Noumea and the Permanent Commission for the South Pacific in Bogota.

It is essential to bear in mind that all components of a regional programme are interdependent. Assessments identify the problems that need priority attention in the region. Legal agreements are negotiated to strengthen co-operation among States in managing the identified problems. They also provide an important tool for national policy-makers to implement national control activities. Management, aimed at controlling existing environmental problems and preventing the development of new ones, is one of the means by which States fulfill their treaty obligations. Co-ordinated assessment activities then continue to assist Governments by providing scientific information by which to judge whether the legal agreements and management policies are effective.

The key to the success of any regional seas action plan is the political agreement of the Governments concerned and the execution of the programme primarily by national institutions from the region, in close co-operation with the relevant specialized organizations of the UN system and other appropriate organizations relevant to the region. The successful implementation of any regional seas action plan also depends on sound preparations which take into account the specific socio-economic and political situation in a given region, the priorities in environmental protection as defined by the Governments of the region, the recognized capabilities and needs of the national institutions which are participating in the action plan, and the results of past and ongoing activities.

Consultations with the Governments concerned are essential for the preparatory phase of a regional programme. As a result of such consultations the general strategy for developing a regional programme is clarified, priority programme elements are identified and the timing of, and responsibility for, substantive actions is determined.

The procedures and activities followed in developing an action plan are instrumental in obtaining the Governments' and experts' long-term commitment to the action plan. Without a strong governmental commitment and a realistic programme supported by experts from the region, efforts to promote regional environmental co-operation would be short lived.

ACHIEVEMENTS OF THE ACTION PLAN FOR THE EAST ASIAN SEAS

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ABSTRACT

The East Asian Seas Action Plan was adopted by Indonesia, Malaysia, the Philippines, Singapore and Thailand in 1981 for the development and protection of the marine environment and coastal areas for the promotion of the health and well-being of present and future generations. The participating countries have evolved generally efficient mechanisms for programme management and project implementation with technical assistance from UNEP. They have also established a Trust Fund which provides partial support to the programme activities.

A dozen projects were implemented by international organizations in the preparatory phase before 1981 while about half this number are currently being implemented by national institutions in the region. These include studies on oceanographic phenomena in relation to pollution, oil pollution, non-oil pollution, coral resources and the effects of pollutants, the establishment of a regional data exchange system, and oil spill contingency planning. A project on the cleaning up of urban rivers has been completed. Three new projects are about to be initiated.

In the implementation of the action plan several dozen national institutions have been involved and nearly five hundred national experts have benefitted from training activities. Consequently, there has been an improvement in government awareness of environmental concerns in the marine realm which is slowly being translated into policies and measures in consonance with the objectives of the action plan.

Introduction

An overview of the East Asian Seas (EAS) Action Plan (Snidvongs, 1985) was presented at the UNEP-sponsored symposium that was held in 1983 during the 15th Pacific Science Congress in Dunedin, New Zealand. Hence, this paper will only briefly summarize the background of the East Asian Seas Action Plan. Instead, it will focus on its achievements.

After a series of preparatory projects and several meetings held on the initiative of UNEP, the Action Plan was finally adopted in April 1981 in Manila, Philippines, during the Intergovernmental Meeting on the Protection and Development of the Marine Environment and Coastal Areas of the East Asian Region. The principal objective of the EAS Action Plan is the development and protection of the marine environment and the coastal areas for the promotion of the health and well-being of present and future generations. The EAS Action Plan aims to provide a framework for a comprehensive and environmentally sound approach to coastal area development particularly appropriate to the needs of the countries in the region.

There were a dozen projects which were implemented during the preparatory phase supporting the adoption of the action plan through the help of international organizations. Their support was very significant in terms of facilitating the formulation of the action plan which was to be carried out immediately. For example, support from FAO, IMO, Unesco and WHO to the training activities related to the action plan was generous and efficient.

Since the adoption of the action plan, the initiative for programme activities shifted to national institutions with the support of the Programme Activity Centre for Oceans and Coastal Areas of UNEP, although some international organizations collaborate in the implementation of some projects.

The Co-ordinating Body on the Seas of East Asia (COBSEA) was established by the governments concerned as the policy co-ordinating unit with the overall authority to determine the content of the action plan, to review its progress, and to approve its programme of implementation including the financial implications (Snidvongs, 1985). The COBSEA is composed of the UNEP focal points who are also the representatives to the ASEAN Experts Group on the Environment (AEGE). This group has requested UNEP to take care of the overall technical co-ordination and supervision of project implementation.

Funding of the EAS programme has been provided by Trust Fund contributions from the five participating countries and by matching funds from UNEP. Although the intention is for UNEP support to be replaced eventually by national contributions, to date this counterpart support has been significantly greater.

Achievements

The evaluation of the action plan has been addressed in the document The East Asian Seas Action Plan: Evaluation of its Development and Achievement (UNEP/IG.77/INF.3), in which the coordinator of this symposium and the author actively participated. This paper will not attempt to duplicate this evaluation, but will focus on the author's perception of what has been achieved, mainly from the perspective of the region.

The first achievement was the adoption of the action plan itself. Previous to the initiation of the programme, the countries of the region had no integrated activities to address the problems of the marine environment. The entry of UNEP was timely, for the AEGE was just in the process of developing regional activities concerned with the environment in general. While it may be said that the experts group would have eventually come up with its own marine programme, it is probably safe to say that the UNEP-sponsored Regional Seas Programme in South-East Asia is the most significant, if only from the funding aspect, of the regional environmental activities up to the present time.

Through this action plan, scientists and environmentalists concerned with the protection of the marine environment have been able to broaden their focus from a national to a regional perspective. There is now a real mechanism for addressing marine problems on a regional scale.

The second achievement is intimately related to the first. This is the establishment of the trust fund for the implementation of the action plan. The fact that the participating countries have allocated monies for activities related to marine environmental protection is a definite sign of commitment not previously witnessed. The EAS Trust Fund is presently on the order of $100,000 per year, with contributions ranging from $1,100 to $33,000 per country. While it may be observed that the contributions are modest in absolute terms, they are in fact significant if viewed from the regional perspective. The ASEAN countries are all considered developing, with the possible exception of Singapore. A look at the share of the environment in national budgets will reveal a very modest percentage. If the trust fund contributions are viewed in this light, they are not insignificant. It is everyone's hope, however, that these contributions will increase significantly with time because of the magnitude of the tasks to be accomplished.

In addition to contributions in cash, the mobilization of "men and material" in the participating countries has been increasing rapidly. No cash value has been put on these contributions in kind, but they are now significant. Some four dozen national institutions and agencies have participated in the implementation of programme activities. The number of people that they have involved in action plan related activities is an order of magnitude higher.

The reciprocal accomplishment has been the benefits accruing to institutions and to their personnel, although the emphasis has been on the latter. At least half a dozen institutions have received equipment and supplies for the conduct of project activities. Although this has not been the thrust of the technical assistance of the Regional Seas Programme, the equipment that has been acquired can be considered substantial for a few of the institutions concerned. In addition to the material benefits, some three dozen experts from within and outside the region have been recruited to serve various needs of the projects for short periods of time.

Perhaps the most noticeable or significant achievement of the EAS Action Plan has been in the training provided to participants in the various projects in the region. Since the first preparatory workshop held in Penang in April 1976, scientists and environmental managers from the region have been given opportunities for training on some thirty occasions, usually workshops or training courses held within the region. There have been a number of occasions where scientists from the EAS region have been sent for individual or group training to such places as Sydney, Australia and Tahiti, French Polynesia. On the other hand, the EAS programme has also served as host to several dozen trainees from East Africa to American Samoa. By last count, nearly 500 opportunities for training have been provided by the programme. Even if not all of these trainees remain active in the action plan activities, the Regional Seas Programme has nevertheless contributed significantly to manpower development in a tropical region where such training is much needed and desired.

The EAS Action Plan was only adopted five years ago. As previously mentioned, about a dozen projects were executed during the preparatory phase. Since the start of the implementation of the action plan half a decade ago, only one project has been completed. Half a dozen are being implemented, of which three are to be concluded within the year, to be replaced by three new projects (Table 1). Because of the generally slow processes involved in data collection prior to scientific publication, the output of papers has been limited, apart from the technical reports required of the various projects. It is anticipated, however, that with all the training that has been provided, the scientific output will be multiplied.

The real test of the success of the EAS programme will be in the attainment of its objectives. A fledgling programme is not expected to have achieved its long-term objectives in the space of half a decade. The marks of success of the programme no doubt vary from country to country, depending in part on the vitality of the leadership of the focal points who co-ordinate their respective country programmes. In the more active countries, the East Asian Seas Programme has influenced the environmental agencies to focus more attention on the marine realm. Concomitant with this is the increasing awareness of the legislators and the decision-makers of the need to protect the marine environment. Indeed, although it is not clear to what extent there is a cause and effect relationship, there is a strong positive correlation in some countries in the region between the development of the action plan and the adoption of policies and measures related to the conservation of marine resources and the protection of the marine environment.

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Table 1. East Asian Seas Projects

Project Title	Implementing Institution
Preparatory Phase	
International Workshop on Marine Pollution in East Asian Seas	IOC/FAO (IPFC)
Oil Pollution Contingency Planning for the Straits of Malacca and Singapore Region - Preparatory Stage	IMO
Programme Activity Centre for Regional Seas	UNEP
Impact of Pollution on the Mangrove Ecosystem and its Productivity in South-East Asia	FAO
Regional Seminar on Environmental Impact Assessment in South-East Asia	WHO
Workshop on Coastal Development and Management in South-East Asia	UN/DIESA-ESCAP
Development of Regional Oil Spill Contingency Arrangements in South-East Asia	IMO
River Inputs to South-East Asian Seas	UNESCO
Research into the Toxicity of Oil Dispersant Chemicals on Tropical and Subtropical Marine Species	IMO
Overview of Land Based Pollution Sources in South-East Asia	WHO-PEPAS
Development of Legal Instruments for the Protection of the Marine Environment in South-East Asia	ESCAP
Assessment of Oil Pollution and its Impact on Living Aquatic Resources in South-East Asia	FAO
Environmental Problems of Offshore Exploration and Exploitation in South-East Asia	ESCAP/CCOP
International Workshop on the Prevention, Abatement and Combating of Pollution from Ships in East Asian Waters	IMO
Development of a Comprehensive Action Plan for the Protection and Development of Marine Environment and Coastal Areas of the East Asian Region	UNEP
Implementation Phase	
UNEP Support for the East Asian Seas Action Plan	UNEP
Co-operative Research on Oil and Oil Dispersant Toxicity in the East Asian Seas Region	MSTE, Malaysia
Study on Coral Resources and the Effects of Pollutants and Other Destructive Factors on Coral Communities and Related Fisheries in the East Asian Seas Region	NRMC, Philippines
Study of the Maritime Meteorological Phenomena and Oceanographic Features of the East Asian Seas Region	NEB, Thailand
Survey and Monitoring of Oil Pollution and Development of National Co-ordinating Mechanisms for the Management and Establishment of a Regional Data Exchange System	MPE, Indonesia
Assessment of Concentration Levels and Trends of Non-Oil Pollutants and Their Effects on the Marine Environment in the East Asian Seas Region	NEPC, Philippines
Implementation of a Technical and Scientific Support Programme for Oil Spill Contingency Planning	MPE, Indonesia
Co-operative Study into the Cleaning-Up of Urban Rivers	MinEnv, Singapore
Development of Training Programmes for Marine Parks (With Emphasis on Coral Reef Marine Parks) Management Personnel	DF, Malaysia
Establishment and Management of Marine Data Base and Information System for the East Asian Seas Region	MPE, Indonesia
Assessment/Overview of Land-Based Sources of Pollution From Coastal Resort Areas in East Asia	MinEnv, Singapore

OCEANIC TRANSPORT OF POLLUTANTS IN SOUTH-EAST ASIA

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ABSTRACT

The natural oceanic transport of pollutants in South-East Asian seas is mainly due to currents, waves and tidal action. Human activities are not a natural cause of pollutant transport but they are a main mechanism in some areas such as the estuaries near big cities in South-East Asia. This study reviews the characteristics of currents, waves and tides and their role in pollutant transport in South-East Asian seas. Of these three mechanisms, wind-driven currents are most important in the open seas and big bays. However near coastal areas, estuaries and channels, tidal currents and wave-driven currents are the most active mechanisms for pollutant transport.

Introduction

The investigation of currents, mixing processes and water exchange with adjacent areas is obviously necessary to understand the problem of marine transport of pollutants. Most pollutants either float on the sea surface or exist in a mixed state in the upper surface layer. The transport of such pollutants is therefore affected by surface circulation. Hence for the South-East Asian coast where different sources of pollution exist, it is essential to know the coastal currents and to understand their seasonal variability in relation to meteorological and hydrological factors and to offshore or interbasin exchange. Salinity and temperature distributions will also influence both the vertical and horizontal spreading of substances and therefore should be determined. Other factors which have a bearing on water quality conditions are waves, tidal variations, turbidity and light penetration. Meteorological and hydrological factors, such as wind strength and direction, the incidence of sunny and rainy periods, temperature differences between land and sea, storm frequency and tracks, precipitation and runoff, all influence coastal water conditions. Some air-sea interactions such as fronts, upwelling, and monsoon dynamics provide additional information on physical processes contributing to the transport of pollutants in the sea.

The extent to which physical processes contribute to the pollutant dispersion will be determined by topographic characteristics (coastlines, bottom slopes, existence of sills), oceanographic characteristics (currents, rate of exchange with offshore waters, vertical gradients and stratification plumes, fronts, etc.), and the characteristics of the pollutant itself (coastal, surface or deep water outfall; jet or diffused discharge; soluble or nonsoluble substance, fate and lifetime, etc.).

Geographical Zones

South-East Asia may be classified into two zones on the basis of sea bottom topography and coastal morphology. The classification provides a convenient and practical means of assessing land-based and marine pollution inputs into the region. Considering geographically defined regions will help to identify areas of concern and may also indicate effects, trends and results of control and management.

I. Coastal zone/short time scale pollution problems. If we consider the South-East Asian continental margin to be in this zone, it covers 2,744,700 square nautical miles (9,424,227 sq. km). Water properties there are strongly influenced by boundaries with the continents or islands and with the sea floor. The coastal sea receives direct injections of continental materials via rivers, direct terrestrial runoff and drainage, and the atmosphere, as well as through such mobilizing agents of man as domestic and industrial outfalls and ships. Most pollution problems are found in coastal zones, shelf seas and semi-enclosed bays where sources of contamination are largely associated with population and industrial centres.

Valencia (1979) showed the significant features of the coastal morphology of South-East Asia (Figure 1).

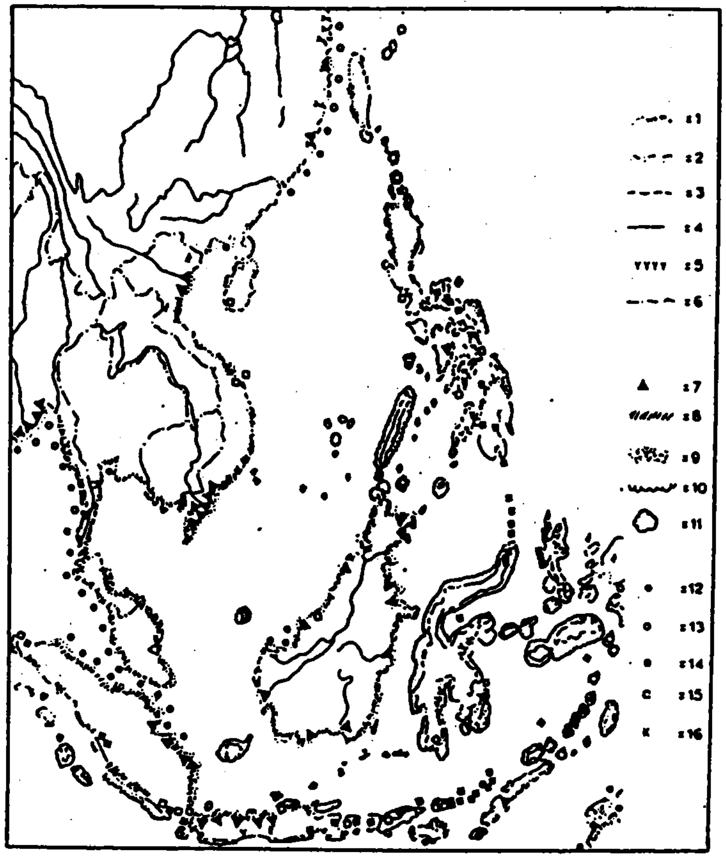


Figure 1. Significant coastal features in South-East Asia (from Valencia, 1979, after McGill, 1958): 1 = plain; 2 = plain <8 km (5 miles) wide; 3 = hills; 4 = mountains; 5 = embayments; 6 = political boundary; 7 = delta; 8 = mangrove (extensive); 9 = dunes and beaches (extensive); 10 = fringing or barrier reef; 11 = isolated reef; 12 = tidal range >3 m (10 ft); 13 = tidal range >6 m (20 ft); 14 = active volcano; 15 = inactive volcano; 16 = karst topography.

a) **Coastal plains** are not a predominant coastal land type as compared to mountains and hills. However extensive coastal plains are found along the western coast of Taiwan, on the Chinese mainland opposite Hainan and on northern Hainan itself, in central and extreme southern Vietnam, the southern Malay Peninsula, the entire north-east coast of Sumatra and north Java, southern Sulawesi and almost all of Borneo.

b) **Deltas** with mud-flats and adjacent nutrient-rich, turbid coastal waters are generally located where the region's major rivers discharge into the sea, e.g. China's Si, Vietnam's Red and Mekong, Thailand's Mae-Klong and Chao Phraya, and Indonesian Borneo's Kapuas.

c) **Mangrove forests** are a predominant coastal feature in northern and extreme southern Vietnam, Cambodia, Thailand, Peninsular Malaysia, Sumatra, north Java, Borneo and the Philippines.

d) **Coral reefs** occur as patches of fringing coral along the land-water interface of virtually all the region, but extensive fringing reefs are limited to the eastern Indonesian Archipelago and the Philippines. Coral fringed islands, atolls and isolated reefs abound in the Gulf of Thailand, the eastern central South China Sea, and throughout the Indonesian and Philippine Archipelagos wherever sufficiently clear water and geological development permit growth.

e) **Sandy beaches** are not a common coastal type in South-East Asia. Extensive stretches of beach do occur in south-west and north-east Taiwan, central Vietnam and along the east coast of the Thai Isthmus and the Malay Peninsula. Smaller stretches of sandy beach are scattered throughout the region.

II. Marginal sea or open ocean zone/long time scale pollution problems. This deep sea zone differs significantly from its coastal counterpart not only in its time scales but also in its relationships with the continents and sediments. The time spans for natural processes extend from hundreds to hundreds of millions of years, as contrasted to decades in the coastal zone. The deeper waters (>100 m deep) are out of contact with coastal waters or surface waters for periods averaging between a few hundred and a thousand years, depending on the specific ocean basin. These waters are receiving some of man's wastes today. The surface of the open ocean is soiled with petroleum products. In addition, ocean currents carry litter, plastics, glass, wood products and metals. Apart from atmospheric deposition, the inputs from shipping reach open ocean waters directly.

A series of deep depressions, called marginal seas, lie between the peripheral island arcs and the continental crust area of South-East Asia (Figure 2). The South China Sea is one of the largest "marginal seas" of the western Pacific, covering about 1.5 million square km.

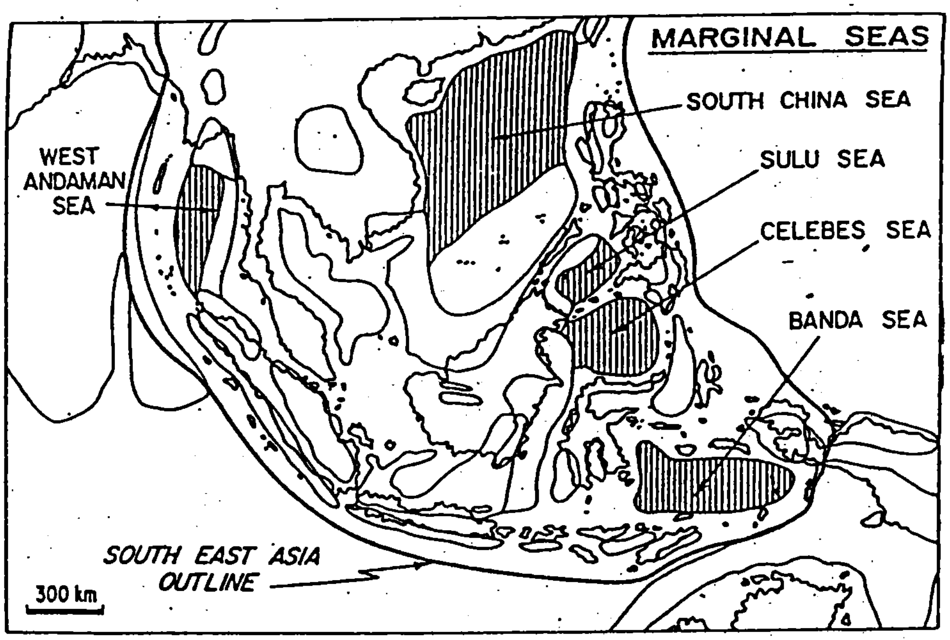


Figure 2: Marginal Seas of South-East Asia (from Murphy, 1975)

The deep marginal seas lie seaward of the continental shelf, and are relatively enclosed. There is a danger of direct pollution from oil-well blow outs, shipping accidents and international discharges.

The protection of the coastal zone is one of the housekeeping problems of coastal nations. The potential pollution of the open ocean may result from the contribution of many nations, all of whom have some economic stake in the loss or restricted use of its resources.

Type of pollutants in the sea

Disregarding the source and transport agent, the physical behavior of pollutants in the marine environment is strongly dependent on their nature and their density. The manner in which a pollutant disperses from a source depends inherently upon whether it is insoluble or dissolves in sea water.

Insoluble substances, with lower density than that of sea water, will float on the surface, whereas a substance of neutral buoyancy, e.g. a colloidal or organic particulate suspension, will float at any level in the water mass and will eventually become adsorbed upon denser organic and inorganic matter, and with it contribute to deposits on the sea floor. A substance of greater density than sea water will sink to the sea bed. The fate of these insoluble substances depends upon these characteristics.

Insoluble substances of low specific gravity will be transported in and on the surface layers and be subjected in particular to wind-induced water movements. Substances of neutral buoyancy will tend to diffuse throughout the whole marine system, and, if they do not become attached to a particle of greater density, will move in a manner characteristic of the hydrography of the individual marine system. An insoluble particle which is more dense than sea water will tend to move in the dense water layers of the marine system according to its buoyancy adjustment. Wood fibres, which are buoyant when first exposed to sea water, but later sink, show an interesting behavior which is intermediate between that of sedimentary and fully soluble wastes.

Soluble substances will at first show the same behavior, but sooner or later, depending on their solubility rate, will be completely dissolved. Gases may dissolve completely or partly in sea water; they usually originate in the atmosphere, but may also come from chemical or biochemical processes in the sea.

Soluble substances which are not precipitated upon contact with sea water will become dispersed by diffusion and transport, initially by an amount which depends upon the tide-induced turbulence (tidal range), and the wave action characteristic of the individual marine system.

The influence of physical properties on pollutant transport in the sea

The static physical properties of the marine environment mainly interact with the properties of the pollutant. Temperature and salinity influence the rates of solubility or precipitation of soluble pollutants or of coagulation of dispersed material. The density of sea water is mainly determined by these two factors, particularly when the density of the pollutants is very near to that of the water. Viscosity, which depends on temperature and salinity, may also have an indirect influence by determining the sinking velocity of particles. Surface tension is a very important factor in its interaction with oil films, etc.

The most important physical influences on the distribution of pollutants are exerted by **movements** of any kind.

The main difference between insoluble and soluble substances becomes evident from their duration of stay in the sea and their place of deposition. Floating insoluble particulate matter is transported at relatively high velocities in the direction of surface wind-driven currents or long-shore drift. Sooner or later the floating matter reaches the shore or some surface where it continues to collect and concentrate. Unless the decay rate for the floating matter is relatively high, a low but steady supply of floating material will build up with time until it reaches significant and possibly objectionable concentrations on the shore, from which it may again be removed by waves or currents.

Neutrally buoyant and soluble substances may stay in the sea for an almost unlimited period, just as sea salts do. Dissolved gases are different from other soluble substances because the vapour pressure always balances that of the atmosphere.

Physical processes of pollutants in the sea

The spectrum of movement in the sea extends from molecular dimensions to ocean-wide current systems. The irregular multi-directional motion of turbulence causes mixing processes very similar to that of molecular diffusion but with much greater efficiency. This effect is usually known as **eddy diffusion** and it differs from molecular diffusion in the variability of its coefficients which are not as clearly defined as a function of temperature as are those of the molecular processes.

Factors such as current velocity, depth, density stratification, wind velocity with fetch length, and density differences between effluent and receiving waters all influence the process of turbulent diffusion.

Eddy diffusion is responsible for the mixing and dilution of pollutants. **Transport** is possible only by currents which have directional motion but which may also be turbulent. The difference between "turbulence" and "current" depends on the time and spatial scales under consideration. An example of this is a tidal current which is uni-directional but has real transport capability only if considered for one half of a tidal cycle. If averaged over many tidal cycles or if considered within a greater current system, e.g. the Kuroshio, the tidal ellipses have the character of turbulence elements.

There are various physical processes which contribute to mixing in the coastal zone. **Longitudinal dispersion** arises from a number of interactions between advective movements and turbulent diffusion. **Vertical mixing** relative to the degree of stratification is brought about by the turbulence associated with bottom friction of shear flows at mid-depth. **Lateral mixing** is influenced by the irregularities in the coastal boundaries and the sea bed.

Water movements alone cause an **advective** transport of properties and lead to **dispersion** when the current velocity varies with position, but **turbulent diffusion** is also needed in order to produce mixing. For example, vertical or horizontal shear in the current stretches or distorts an initially compact distribution of pollutant, producing sharp concentration gradients. This increases the rate of turbulent diffusion, which is usually taken as being proportional to the concentration gradient. **Molecular diffusion** is generally neglected, as in most problems involving dispersion in the sea, its effects are several orders of magnitude smaller than those of turbulent diffusion.

Transport processes are generally unsteady. Therefore the advective terms that describe the fluid flow must be determined by simultaneous solution of the continuity and momentum equations.

The flow in estuaries is nearly always turbulent, and this characteristic affects the mechanics of the flow and its dispersive effects. In one sense all physical processes in estuaries can be described as turbulent. Turbulent processes originating at the surface are by no means negligible in estuaries, but they are generally less important than they are in open coastal waters.

Viewed on a small scale, the ocean is not turbulent everywhere. On the contrary, turbulence in the deep ocean occurs only intermittently and in patches (which are often thin and horizontally elongated), while the level of fluctuations is very low through most of the volume for most of the time. This is a consequence of the stable density gradient, which can limit the vertical extent of mixing and thus keep the relevant Reynolds numbers (the parameter which defines laminar or turbulent flow) very small.

Eckart (1948) pointed to the distinction which should be made between **stirring** and **mixing processes.** The former always increase the gradients of any patch of marker moving with the fluid, as its boundaries are sheared by the larger eddies of the motion. True mixing is only accomplished when molecular processes, or much smaller scale turbulent motions, act to decrease these gradients and spread the marker through the whole of the larger region into which it has been stirred.

The concept of **diffusion** may be viewed simply as the tendency for a group of particles initially concentrated near a point in space to spread out in time, gradually occupying a larger area around the initial point. Diffusion is a phenomenon by which the particle group as a whole spreads according to the irregular motion of each particle.

The major physical processes affecting pollutant transport in the sea are as follows:

1. **Solar radiation.** The direct effect of solar radiation is to produce thermal stratification in the near-surface layers of the sea. This may change the static properties of the

water, and also influence the vertical component of turbulence. The thermal layering - in extreme cases forming a sharp thermocline with strong vertical gradients - increases the stability of the density stratification. Vertical turbulence, such as from wind or waves, can only transport surface water downwards by sacrificing part of its energy to overcome the potential energy of the stable layering.

Negative radiation at night or in the fall and winter seasons reduces the stability of the surface layers. When surface water becomes denser than lower layers, vertical convection starts, producing turbulence even in the absence of other types of turbulence. However the vertical mass exchange due to the vertical component is not impeded by the potential energy of the masses. Similar effects can be produced when cold or warm air masses meet with sea currents flowing parallel to meridians of longitude, thus having temperatures different from those of the sea surface.

2. **Wind waves.** Probably the most important and effective source of deep sea energy is the wind which produces wind waves. Since surface waves are not merely periodical displacements of the mean water level but also have deep-reaching orbital motions below the surface, their influence on mixing and dispersion of pollutants is considerable. Wind or storm waves are different from the swell from distant wind fields, with the latter being much less turbulent than wind waves. Breaking waves transform much of their energy into small-scale turbulence which rapidly disperses floating pollutants. However an oil film on the sea surface helps to prevent the breaking of waves. The depth of the vertically mixed layer produced by wind waves is usually indicated by a mixed isothermal layer above the thermocline.

Wind-driven currents. The second important wind effect on the water surface is wind stress, resulting first in a surface drift, and then, by internal friction, in a drift current increasing with depth (as described theoretically by Ekman). Both of these effects are important for pollutants. The surface drift transports oil films and other floating substances which "sail" with the wind at a velocity higher than that of the water. The vertical shear of the Ekman current speed and direction combined with orbital wave motions may produce very complex mixing patterns for dissolved substances. Drift current patterns become still more complicated in the presence of bottom friction, coastlines, etc. Water piled up by onshore winds or upwelling generated by offshore winds result in additional vertical components and thus in increased vertical mass exchange. The need for mass balance usually results in a compensating current near the bottom or in intermediate depths in the direction opposite to the surface current. In this way it is possible for pollutants deposited on the bottom some distance from shore to be transported back to the shore.

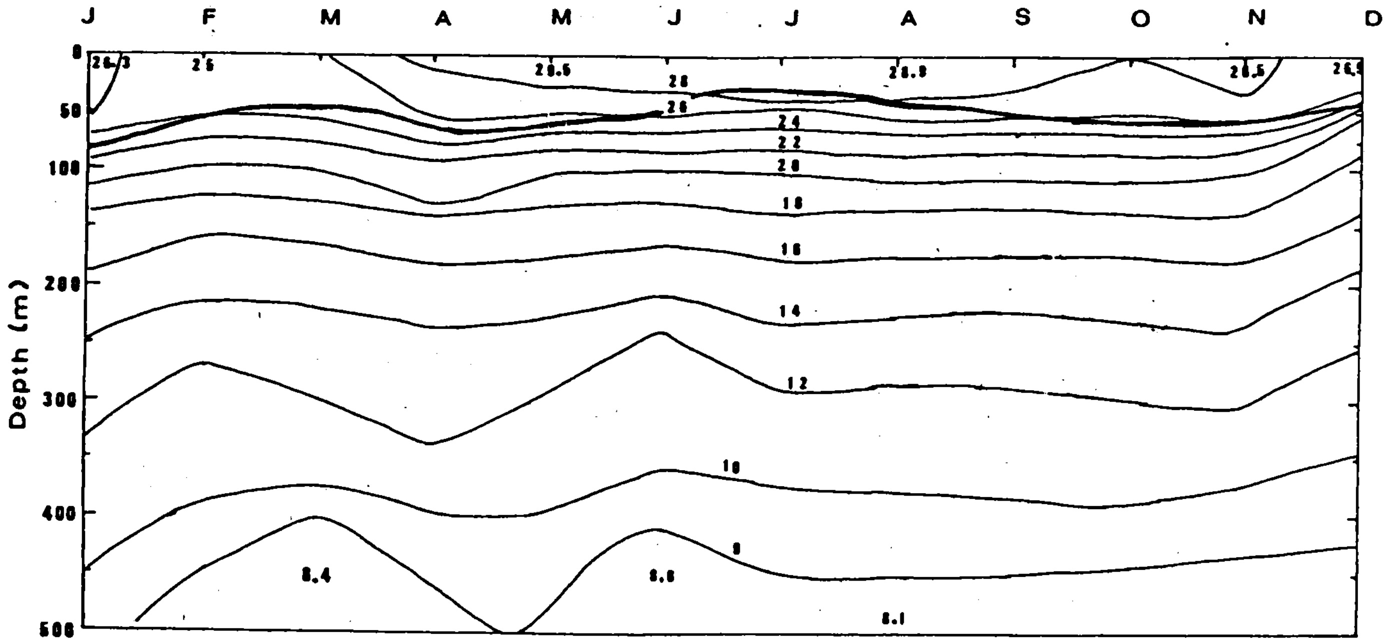
4. **Density currents.** Other sources of energy are currents produced by density gradients, e.g. as a result of tidal currents, intrusions of fresh water, or salinity differences between different sea regions such as the South China Sea and the Pacific. Although density currents are usually clearly directed, typical tidal currents periodically change their speed and direction. The effect of tidal currents should therefore be that of a turbulent element without essential net transport; however most tidal currents, when integrated over longer periods, yield residual currents which may reflect the mean density current in that region or the effect of wind drift during the integration interval. Areas with tidal currents have higher eddy diffusion coefficients than tideless regions, assuming the same weather conditions (Weidemann and Sendner, 1972).

Transport of pollutants in South-East Asian Seas

Deep sea area

a) Water stratification. There are three layers of vertical structure in the deep seas of South-East Asia: an upper layer, the thermocline, and a deep layer. The upper layer extends from the sea surface down to a depth ranging from 50-200 m depending on the season. It is rather homogeneous, though its properties vary seasonally. The annual variation of the mixed upper layer depth shown in Figure 3 is based on all bathythermograph and oceanographic station data at Lat. 15-16°N and Long. 119-120°E. The mixed layer is shallowest in June-July which is summer, and deepest in January during winter. This layer contains the most intense currents, waves and turbulence in the sea.

Figure 3
Seasonal variation of thermal structure in the South China Sea
Grid #61-59 (Lat. 15-16°N, Long. 119-120°E)
Temperature in °C. Mixed layer depth indicated by thick line.



Below the upper layer is the thermocline zone with a strong density gradient. It acts as the barrier to vertical mixing. The deep layer occupied by cold dense water extends beneath the thermocline to the bottom of the sea. The seasonal variations of temperature and salinity averaged from historical oceanographic station data from Lat. 3°S to 24°N and Long. 99-121°E are shown in Table 1.

Table 1: Seasonal variations in temperature and salinity in the South China Sea
Lat. 3°S-24°N, Long. 99-121°E

Average temperature (°C)

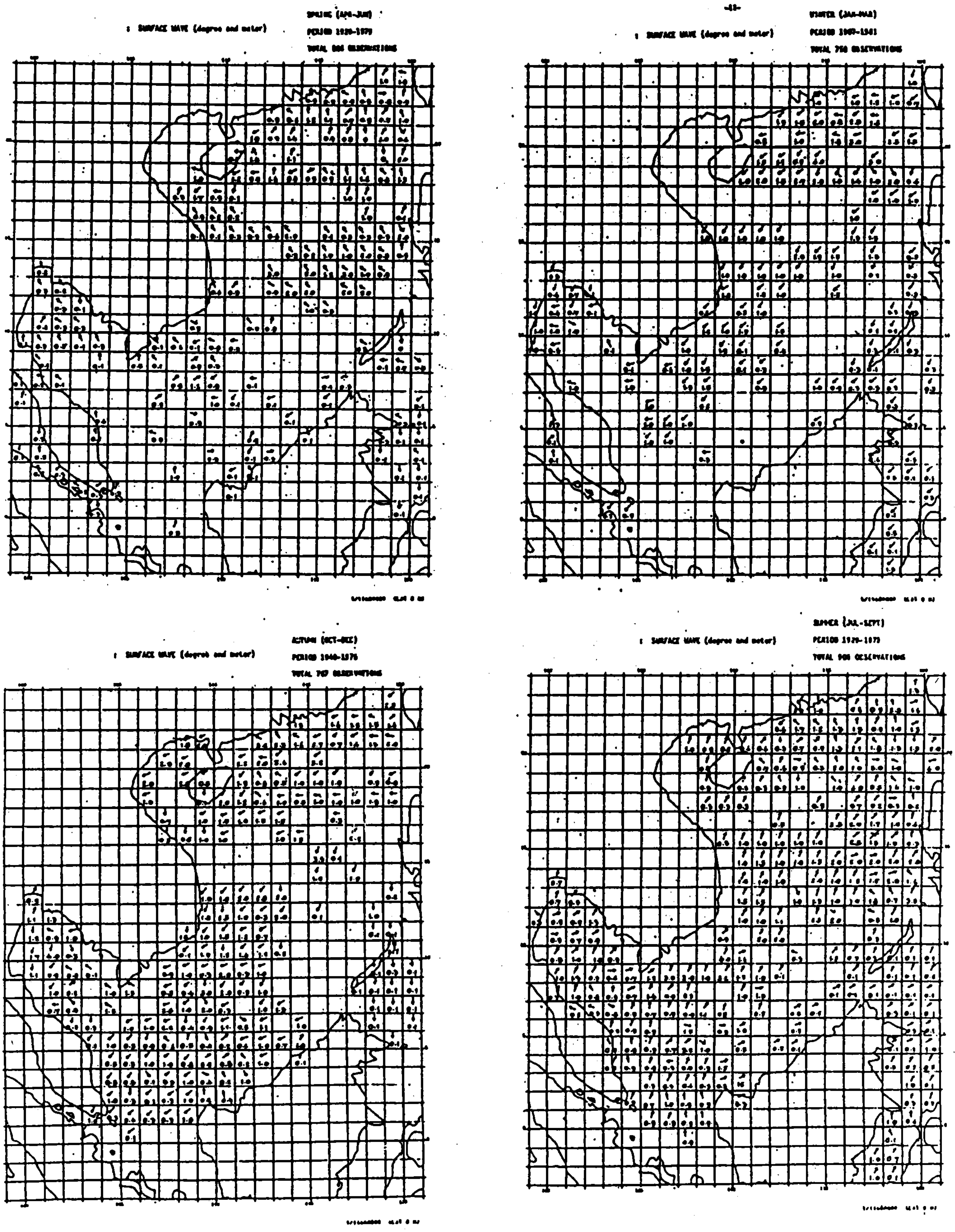
Depth (m)	Winter	Spring	Summer	Autumn	Year
1	25.84	28.69	28.83	27.64	27.75
50	25.07	25.87	26.43	26.60	25.99
100	22.02	25.06	21.63	21.82	22.63
200	15.65	17.28	15.72	15.89	16.13
500	8.22	8.44	8.17	8.41	8.31
1000	4.43	4.49	4.46	4.47	4.46
2000	2.45	2.65	2.87	2.71	2.67
4000	2.44	2.45	2.85	2.48	2.55

Average salinity (o/oo)

Depth (m)	Winter	Spring	Summer	Autumn	Year
1	33.29	33.27	32.90	32.65	33.03
50	33.86	33.92	33.80	33.61	33.80
100	34.39	34.45	34.45	34.46	34.44
200	34.55	34.54	34.54	34.56	34.55
500	34.47	34.44	34.46	34.45	34.45
1000	34.54	34.53	34.54	34.54	34.54
2000	34.60	34.59	34.59	34.58	34.59
4000	34.61	34.58	34.58	34.62	34.60

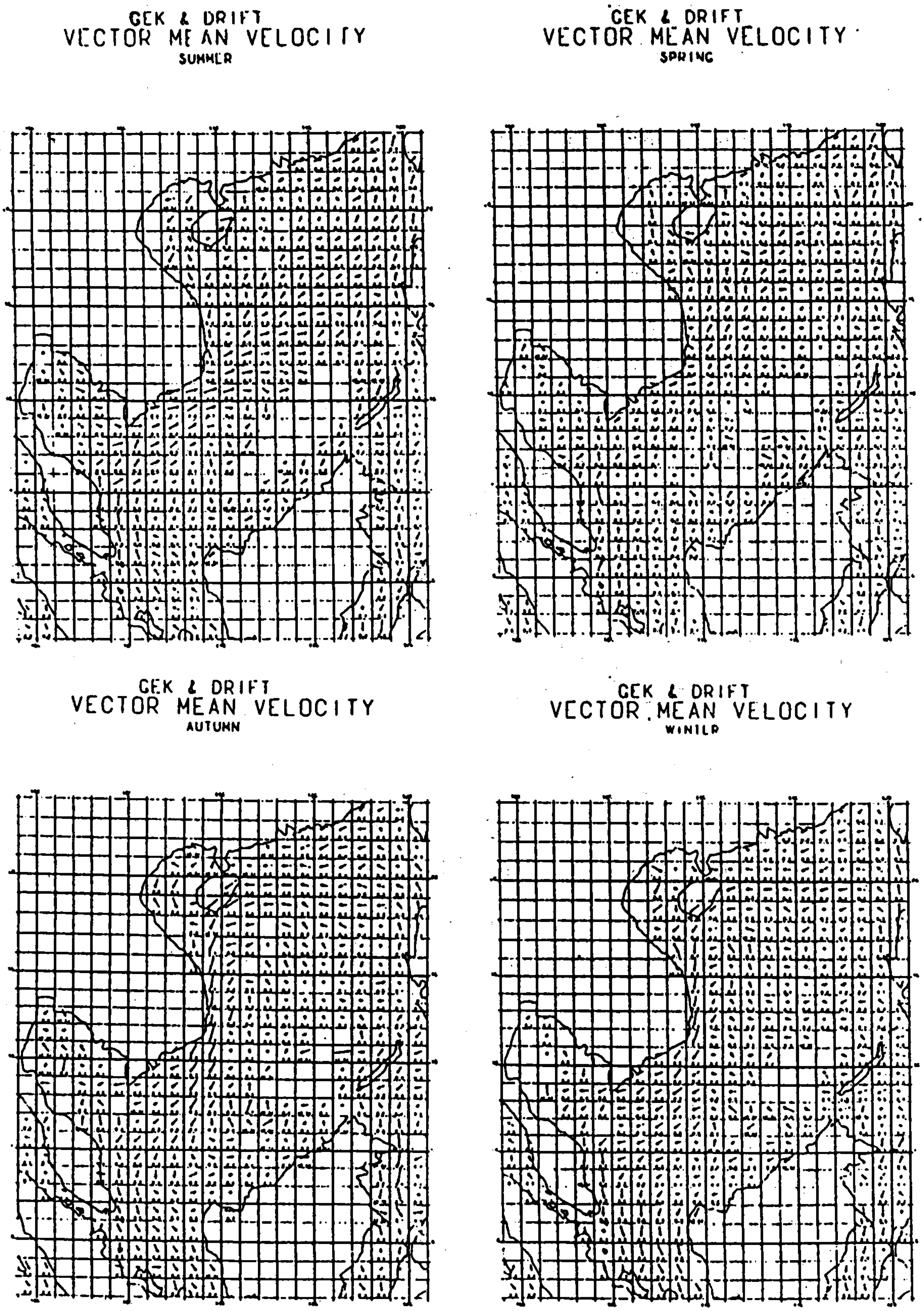
b) **Wind waves.** Figure 4 shows the wave directions and heights in metres in the study area on a seasonal basis.

Figure 4: Seasonal wave directions and heights (m) in the South China Sea area



c) **Wind-driven currents.** Figure 5 shows the surface currents by season based on GEK and ship's drift data.

Figure 5: Seasonal surface currents in the South China Sea area
Vector mean velocity from GEK and drift



Coastal sea area

Currents in the coastal sea may originate as tidal currents, wind-induced currents, density currents, or those induced by fluctuations in ocean currents. In coastal areas facing the open sea, currents induced by the wind or by meanders of ocean currents are generally predominant. Near river mouths such as the upper Gulf of Thailand and the mouth of the Mekong, etc., density (estuarine) currents and tidal currents are most important. In channels connecting two ocean basins, tidal currents and wind waves interact producing whitecaps and turbulence. Oceanic fronts have been reported from many places by Siripong (1980) using satellite data, and these require further study. From a pollution perspective, fronts are very efficient at concentrating buoyant and suspended particulate matter including toxic wastes. Frontal circulation affects the dispersion of oil spills and ocean dumped contaminants. The study of oceanic fronts must be incorporated into environmental monitoring and sampling design if we are to determine effectively how pollutants are transported, concentrated and incorporated into the marine food chain.

Except for a few physical measurements at the Bang Pakong River mouth (Siripong et al., 1984), the Petchburi River mouth in the upper Gulf of Thailand (Siripong and Tamiyavanich, 1984) and in Phang-nga Bay (Siripong, 1987), there are not many coastal current surveys in South-East Asian seas.

Siripong (in press) summarized the characteristics of tidal currents in the Gulf of Thailand as follows:

a) Most of the year, the speed of the tidal current along the east coast is generally in the range of 1-2 knots. Along the west coast, current speed is 2-3.5 knots and may reach 5 knots when it is influenced by a strong monsoon. In the northern part of the inner Gulf, the periodic tidal current usually ranges from 0.5-1.5 knots. However during a strong monsoon, the combined effects of winds and tide may result in coastal currents of 4 knots or greater. The tidal currents in the Gulf are diurnal in character, setting in one direction for 8-12 hours with an intervening slack period of 2-4 hours.

b) The currents along the eastern coast of Peninsular Malaysia in general follow the pattern of the currents in the South China Sea. During the NE monsoon the set is S or SE and during the SW monsoon the set is N to NNW. During fine and moderate weather, the currents are tidal in character. The tidal current off the eastern coast of Peninsular Malaysia is weak (seldom exceeding 1.5 knots) and is mostly masked by the monsoonal currents.

c) At the river mouths, strong tidal currents with a speed of 2-3 knots set in and out of the river. After heavy rains, the speed and duration of the outgoing stream will be increased.

Conclusion

The study of the transport of pollutants in the sea requires different research strategies for two zones: the deep sea and the coastal areas, since the methods of study, sampling and analysis are different in both spatial and temporal scales. Interpretations based only on chemical, biological or geological parameters are inadequate since everything in the sea is always in motion. It is necessary to understand the physical processes in the marine environment in order to predict and control pollution problems.

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THE EFFECT OF MARINE RESERVES ON FISHERIES YIELDS

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ABSTRACT

Marine reserves have been established in the central Philippines for the dual purposes of protecting the coral reef environment and of enhancing fish yields. The available data from one of the reef systems which had been under protective management for ten years prior to violations of the reserve in early 1984 provide evidence that protection played an important role in the maintenance of high abundance and large biomass of fishes in the reserve (sanctuary) and high fish yields in the adjacent non-reserve (fishing area). The high fish yields were most likely due to the export of adult fishes from the reserve.

Introduction

Fishing is the most important exploitative activity occurring on Philippine coral reefs. Estimates of reef fishery production run as high as 24-30 tons/sq.km/yr (Alcala and Gomez, 1985), and reef fish may constitute at least 8-20% of the total fish catch in the country (Gomez and Yap, 1985). Fishery yields of reefs in other areas of the tropical Pacific are also generally high (reviews by Marshall, 1980; Marten and Polovina, 1982; Munro, 1983; Munro and Williams, 1985).

Degradation of coral reefs in the Philippines and the East Asian Seas Region has been discussed extensively by several authors (e.g., Gomez et al., 1981; Yap and Gomez, 1985; Alcala et al., 1987). This destruction may have reached such serious proportions as to have caused a decline in the supply of reef fish. For example, Luchavez et al. (1984) reported very low fish production from a heavily damaged reef in southwestern Negros. Earlier, Smith et al. (1980) concluded that shallow water fisheries in the Philippines are mostly depleted. Much effort has therefore been spent in protecting coral reef areas in the Philippines in order to maintain, if not enhance, fisheries yields. Establishment of marine reserves is also an on-going activity in other parts of the East Asian Seas region (Yap and Gomez, 1985).

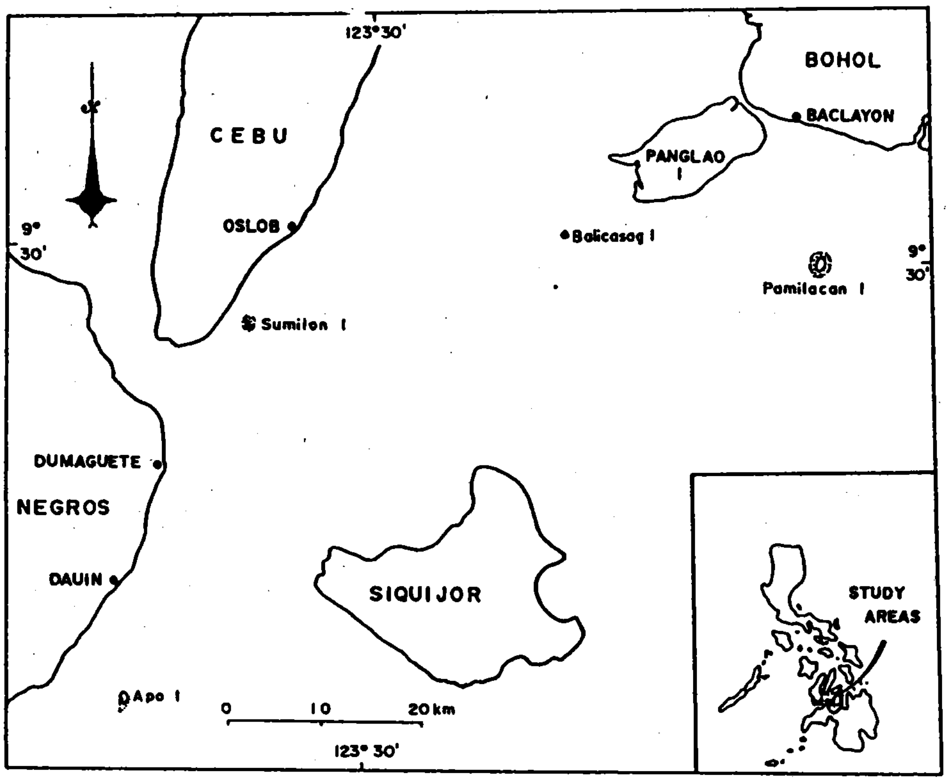
The functions of reserves in fishery management have been well stated by Russ (1985) as follows: (1) species richness and abundance are maintained and possibly increased; (2) sanctuaries provide undisturbed breeding sites; (3) sanctuaries export fish biomass through emigration of adult individuals; and (4) sanctuaries export fish biomass through larval dispersal. Russ (1984, 1985) provided some evidence for the first three expectations but pointed out the paucity of information that relates reserves directly to fish yields. In this paper I present more evidence for the third expectation, the export of fish biomass through emigration, using data from four protected reefs in the central Philippines.

Marine reserves in the Philippines

In this paper, the terms "reserve" and "sanctuary" refer to that portion of a reef system which is totally protected from all forms of exploitation. The rest of the reef "non-reserve" is open to fishing with traditional types of gear or fishing techniques which do not destroy the reef environment. These techniques exclude dynamite-blasting, muro-ami (drive-in net), chemical poisoning and electric fishing. Reserves and non-reserves are therefore subject to varying degrees of protection.

Sixteen marine parks and reserves have been reported from the Philippines (White, 1981), although only one was actively protected at that time (Yap and Gomez, 1985). Five marine reserves have been established in the central Philippines during the past 13 years (Figure 1): one on the 200 ha Carbin Reef off northern Negros Island, and four on the small islands of Sumilon (off southeastern Cebu Island), Apo (off southern Negros Island), Balicasag (off southwestern Bohol Island), and Pamilacan (off southeastern Bohol) (Alcala, 1980, 1981, 1985; Marine Conservation and Development Program, 1986). These reserves vary from about 8 to 20% of the reef areas, with a range from 31 to 200 ha (mean 113 ha). All except one (Sumilon) are actively protected by local communities. The legal basis for these reserves is the local municipal ordinance, except for Sumilon, which derives its protection from a Fisheries Administrative Order of the Bureau of Fisheries and Aquatic Resources.

Figure 1: Location of the four reserves (Sumilon, Apo, Balicasag and Pamilacan) in the Central Visayas, Philippines



Abundance, species richness and standing stock of fishes in reserves

Russ (1984, 1985) studied these three parameters in the Sumilon, Apo and Balicasag Reserves (the last one was not declared a reserve until 1985). His data, gathered with the use of the visual fish census technique, showed that Sumilon Reserve, which was actively protected for 10 years, had significantly higher numbers of individuals for practically all categories of fishes, particularly planktivores, detritivores, coral feeders and piscivores, than either Apo Reserve, which had limited protection from 1982 to 1985, or Balicasag Reserve, which had no protection at the time of the study. He concluded that protective management had played an important role in maintaining the high abundance of fishes in the Sumilon Reserve.

Especially noteworthy were the significantly higher density and standing stock of highl desired or "target" species, the groupers (serranids), at Sumilon, compared to Apo o Balicasag. Again, protection was very important in the maintenance of this high density an standing stock.

However, in terms of species richness, Sumilon did not differ significantly fror Balicasag, and both reserves had higher species richness than Apo. Sumilon had higher specie richness than Apo or Balicasag for labrids, some chaetodontids, serranids, carangids, lutjanid and lethrinids. Despite this, Russ (1984, 1985) considered species richness as a less sensitiv variable in differentiating between sites.

Russ' data for the reserve and non-reserve at Apo did not show significant difference in either species richness or abundance between 1983 and 1985, indicating that the effect o the reserve was not yet evident. However, White (Marine Conservation and Development Program, 1986) reported significant increases in both species richness and abundance o certain fish families at the Apo, Balicasag and Pamilacan Reserves between 1985 and 1986, although his data appear to indicate significant increases in abundance only, not specie richness.

Fish yields of non-reserves

Fish yields of the Sumilon, Apo and Pamilacan non-reserves have been studied (Alcala, 1980, 1981; Alcala and Luchavez, 1981; Alcala and Gomez, 1985; Bellwood, unpubl. data; Alcala, unpubl. data). The estimates are based on monthly samples of fish catch varying from several days to practically all the days of the month for any one study. For Sumilon an increasing trend in fish yields was detected, from about 14-24 tons/sq.km/yr to 36.9 tons/sq.km/yr, during the 10-year period of protection (1974-1984). Apo non-reserve had a yield of 16.75 tons/sq.km/yr (corrected figure from the 11.4 tons reported earlier by Alcala and Luchavez, 1981). In 1986, Bellwood (unpubl. data) estimated the finfish yield of the island at 24.86 tons/sq.km/yr. Alcala (unpubl. data) estimated the fisheries (finfish and invertebrate) yield of Pamilacan non-reserve at 10.94 tons/sq.km/yr on the basis of limited data gathered during 10 months in 1986; if only finfish are considered, the fish yield is a low 7.88 tons/sq.km/yr.

It is unlikely that the reserve on Pamilacan had any positive effect on the fisheries yield. Neither can the Apo Reserve be expected to affect the yield substantially, having been established only a few years ago. But the very high yields of the Sumilon non-reserve were most likely the result of protective management.

Effects of withdrawl of protection

If protective management was responsible for the high fish densities, fish standing stocks and fisheries yields, then withdrawl of protection should result in significant decreases in these variables. A natural experiment provided an opportunity to test this hypothesis. Beginning in May 1984, three months after the completion of the survey by Russ mentioned earlier, violations of the Sumilon Reserve by fishermen began. The reserve was subjected to heavy fishing pressure, including the use of fishing techniques destructive of the coral environment such as dynamite blasting and muro-ami. In December 1985, a re-census of Sumilon was conducted by Russ, and from December 1985 through December 1986, another study of the fish yield was conducted by the author.

Changes in species richness and abundance. Russ (1986) showed little change in species richness but a distinct drop in the numbers of individuals at the Sumilon Reserve between 1983 (period of protection) and 1985 (period of violation), indicating that species richness is not a good indicator of fishing pressure. In the control sites no such drop in individual numbers occurred. The decreased density in the Reserve was mainly caused by a 35% drop in the numbers of the planktivorous fusilier Pterocaesio pisang, although other planktivores also contributed to the drop. The chaetodontids, which feed on corals and mobile invertebrates, declined in species richness by 60% and in numbers by 75%. The serranids decreased in density by 45% and in standing stock by 36%; the largest serranid individual in the reserve (Epinephelus fuscoguttatus), estimated to weigh 3.6 kg, disappeared. But the most spectacular decline in numbers (94%) was that of the lutjanids and lethrinids, considered by Russ (1986) "the best indicators of the dramatic increase in fishing pressure in the reserve." There is no question that protection was responsible for the maintenance of high abundances, and in some cases high biomass, of fishes in the Sumilon Reserve.

Change in fish yields. From December 1985 to December 1986, we gathered data on the fish catch (from Sumilon Reserve and non-reserve) on four to five days chosen randomly per month, including two Fridays when trap fishermen landed their catch. The catch per man per trip (catch per unit effort, CPUE) for three types of gear (trap, hook and line, and gill net) was determined; these were compared with the CPUE's for the same week and month during the period of protection in 1983-1984. The numbers of fishermen for which the CPUE values have been derived were mostly from 4 to 88. Five values were based on less than four fishermen; these were not considered critical, as their exclusion from the statistical analysis did not alter the results. There was no evidence of a change in the number of fishermen fishing at Sumilon during the period of violations. (In 1983-1984, a head count of the fishermen observed fishing gave 180, of which about 100 was the maximum observed at any one time.) In terms of the species of fish caught, no differences were observed between those caught before and after the violations; caesionids and acanthurids made up the bulk of the catch. The statistical test used in comparing the CPUE's during the period of protection and violation was the paired t-test (difference between means; paired observations), included in the statistical package Microstat designed for the IBM-PC-XT computer.

During the first three months of violation in 1984, the fishermen removed 1,840 kg of fish from the Sumilon Reserve, at the rate of 49.1 tons/sq.km/yr (Alcala and Russ, in prep.). This high rate of removal is expected when a virgin fish biomass is being fished down. In contrast, the low CPUE's during the 12 months (December 1985 through December 1986) following the 18 months of violation indicated low fish catches. The CPUE's for all types of gear for this period were significantly lower than those during the period of protection (hook and line: $P<.05$, $t=2.17$, d.f.=10; net: $P=.001$, $t=3.8968$, d.f.=10; trap: $P<.01$, $t=2.97$, d.f.=10) (Alcala and Russ, in prep.). The decline in CPUE occurred despite the larger area fished during the period of violations (reserve and non-reserve) than that during the period of protection (non-reserve).

During the 12-month period of study following the 18-month period of violations, the CPUE's were reduced by 55% for hook and line, 33% for traps and 51% for nets, compared with those during the period of protection. The lower reduction for traps probably indicates that some species, particularly deep-dwelling acanthurids, were less affected by dynamite-blasting. Based on the reductions in CPUE and the relative proportions of fish caught with the three types of gear before the violations in 1983-1984, the estimated fish yield of Sumilon Reef is about 19.87 tons/sq.km/yr, about 55% of the fish yield recorded for the period May 1983 to April 1984 (Alcala, unpubl. data). This reduction in yield is borne out by interviews with fishermen, who generally complained of smaller catches in 1986.

CPUE for Sumilon compared with Pamilacan and Apo

The catch per unit effort (CPUE) at Pamilacan for January-August 1986 was compared with that at Sumilon for equivalent periods before and during the violations, using the t-test (test of difference between two group means; pooled estimate of variance in the Microstat package). For net fishermen, CPUE at Pamilacan was significantly lower than at Sumilon before the violations ($P=.001$, $t=5.47$, d.f.=10), but did not differ during the violations ($P=>.05$, $t=1.4446$, d.f.=10) (Alcala, unpubl. data). Thus on the assumption that CPUE at Sumilon during the period of protection is what might be expected for a protected reef of a low coralline island (Sumilon and Pamilacan are both of this type), it appears that the reserve at Pamilacan had as yet no effect on fisheries yield.

The CPUE for nets and hook and line at Apo for the first four months of 1986 was not significantly different from that at Sumilon before and during the violations ($P>.05$). However, the CPUE for traps at Apo was significantly higher than that at Sumilon during protection ($P>.01$, $t=3.1143$, d.f.=4) and during violations ($P=.01$, $t=3.598$, d.f.=4) (Alcala, unpubl. data). One probable reason for this is that there are fewer traps on Apo than on Sumilon. The effect of the Apo Reserve on the fisheries yield of the Apo non-reserve is not yet clear.

Conclusions and recommendations

The effects of protective management on fisheries yields appear to become evident after a period of more than five years. The effects are reflected in the high abundance of fishes, the large biomass of certain preferred fish species, and the increased fish yields from adjacent non-reserves. The high fisheries yields in the non-reserve during the period of protective management of Sumilon can be attributed, at least partly if not mostly, to the export of adult individuals from the reserve. The Sumilon case provides evidence for the important role of the reserve in the maintenance of high fish abundances and high fish yields.

More protected areas incorporating reserves or sanctuaries should be established in areas where coral reefs and fishery resources are threatened with degradation and/or depletion.

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CONTROL OF URBAN RIVER POLLUTION IN SOUTH-EAST ASIA

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ABSTRACT

In recent years, the accelerated pace of urbanization and industrialization in South-East Asia has imposed a tremendous stress on the region's rivers. The increased discharge of wastes has exceeded the capacities of these rivers to assimilate pollution loads. The beneficial uses of the rivers must diminish unless effective pollution control measures are taken.

In South-East Asia, much emphasis has been placed on the abatement of pollution and the rehabilitation of urban rivers. The measures taken include the clearance of accumulated wastes in the rivers, development of sewerage infrastructure to collect and treat the waste water generated by the population, improved collection and disposal of solid waste, and legislation on pollution control. These nations have set up proper water quality programmes and drawn up policy recommendations and measures for immediate and long term implementation.

The efforts have begun to bear fruit. Significant reductions in the domestic, industrial and agricultural pollution loads have led to the return of marine life in the urban rivers. Continuing efforts to conserve and restore the urban rivers will further alleviate the hazards posed to human health and aquatic life.

Introduction

South-East Asia has emerged as one of the fastest growing regions in the world. Without proper pollution abatement measures, the accelerated pace of development and its attendant increased utilization of resources will lead to negative environmental consequences. The strain that has been exerted on our urban rivers and aquatic systems is a case in point.

Fortunately, the governments in our region are not neglecting the need to safeguard the environment - a task which is made all the more difficult by competing and conflicting wants. This paper discusses the sources of pollution to the major urban rivers in South-East Asia, as well as the strategies and measures that have been adopted to abate the pollution of these rivers.

Indonesia

The JABOTABEK (Jakarta-Bogor-Tangerang-Bekasi) area illustrates Indonesia's efforts to combat the pollution of urban rivers. The area suffers from the most severe pollution problems in the country.

Many factors contribute to the pollution of the rivers. In 1982, about 40% of the refuse generated in central Jakarta did not reach the designated dumping grounds. A large proportion of this refuse was disposed of into the rivers and irrigation canals. Some 10% of the domestic sewage from JABOTABEK is discharged untreated into the rivers, raising the coliform count to as high as 10^6 to 10^{10} per ml. Industrial sewage adds to the pollution load. The heavy nutrient levels in the river water result in the intensive growth of aquatic weeds.

The pollution abatement measures taken are as follows:

Dredging. Mechanical dredging is carried out to remove and prevent a build-up of refuse and aquatic weeds.

Sewerage system. Under the Master Plan of the Jakarta Sewerage and Sanitation Project, sewer reticulation systems will convey sewage for final disposal at sea. By 1985, some 1,800 ha of land within Jakarta had been provided with a sewer system. Some 70% of JABOTABEK is served by cesspits and septic tanks. A pilot plant using the extended aeration activated sludge process has been built.

Industrial wastewater treatment. At present, only the larger industries have installed treatment plants to treat their wastewater. Experimental plants using chemical treatment and biofilters are being tried. Hazardous and toxic wastes are disposed of in three designated sites where these wastes will not pollute surface and ground waters.

Malaysia

Kuala Lumpur, the capital of Malaysia, is located in the most urbanized and industrialized region in the country. The city is drained by 5 rivers, including the Klang River. The city has a population of 1 million, which is expected to increase to 2.2 million by the year 2000.

The city generates 2000 tonnes of refuse per day, which is removed by compaction vehicles. Tractor trailers are used in rural areas and squatter settlements with poor accessibility. Street cleaning is done manually and mechanically. A fraction of the solid waste generated, however, reaches the rivers. Measures being taken to reduce this include the slabbing of drains, installation of trash screens, and desilting of drains.

Intensive development activities result in soil erosion problems. The suspended solids content in the river water as increased 6-fold as a result of this. Dredging work is carried out to remove sediment deposits in the river.

Organic pollution of the Klang River is severe, with dissolved oxygen levels dipping below 1.5 mg/l on occasion. Deterioration is held in check, however, by the requirement for full sewage treatment facilities for new development areas and by the implementation of the Kuala Lumpur Sewerage Scheme. Phase I of the scheme has now been completed.

A number of industries discharge their pollutants into the river system. The authorities serve notices on industries that pollute and also relocate some of the industries under the Kuala Lumpur Structure Plan.

Maintenance of rivers is carried out, including grass-cutting, shrub removal, and cleansing and desilting work. A beautification programme is underway, with provision for pedestrian malls, tree planting and relocation of squatters in the riverine areas.

Further improvement will be achieved through relocation of squatter colonies to areas with proper infrastructure, control of littering and refuse dumping, and waste treatment. The central sewerage system will be extended to serve the entire city. All industries will have to adopt anti-pollution measures. Proper environmental planning and public awareness programmes will help contribute towards further improvements in the water quality of the rivers.

Philippines

The Metropolitan Manila Region has a population of 5.5 million people. Some 10,000 industrial firms, including polluting industries such as textile mills, paper and pulp factories, and tanneries, are located in this region.

Only 12% of Manila's population is served by a sewage collection system. A large quantity of domestic wastewater is thus discharged untreated into the receiving waters. This, together with untreated or partially treated industrial wastewaters, has rendered 4 of the 5 major rivers incapable of supporting aquatic life.

About 70% of the 2,650 tonnes of refuse produced each day is collected. A large proportion of the uncollected refuse, much of it from squatter colonies, finds its way into the rivers.

Several agencies are involved in a co-ordinated programme of water pollution control. Measures that have been taken include dredging and reclamation works, the construction of 40 sewer reticulation projects, enforcement of rules and regulations on water pollution control, water quality and pollution monitoring, and the construction of anti-pollution facilities such as the Solid Waste Management Project and the Lakeshore Interceptor Project.

From the various studies undertaken over the years, a set of policy recommendations has been drawn up. The recommendations include:

a) updating of water quality standards;

b) strengthening and strict enforcement of legislation and rules on pollution control devices;

c) implementing the environmental impact assessment system on a stricter basis;

d) improved co-ordination of the activities of the various agencies; and

e) more incentives for the installation of pollution control devices.

Thailand

The central basin of Thailand has a population of 11.5 million people. It is drained by four main rivers, including the Chao Phraya River that flows through the Bangkok Metropolitan region.

During the dry season, the lower reaches of the Chao Phraya River suffer from serious pollution as a result of low dilution and the heavy pollution load from wastewater discharge.

The main sources of pollution are from domestic and industrial activities, with the former accounting for two-thirds of the total organic load in the river.

In 1985, stream standards and surface water classifications were established. Since 1981, industries, ports and hotels located or to be located along the rivers have to prepare environmental impact assessments. Several plans have been drawn up to combat water pollution. These include:

a) **CDM Master Plan on Bangkok Sewerage and Drainage.** This master plan contains a feasibility study of a comprehensive sewer system to convey municipal and industrial sewage.

b) **Bangkok Drainage and Flood Protection Project.** This proposal will relieve the inner-city drains and klongs of wastewater by draining it more rapidly into the Chao Phraya River.

c) **Master Sewerage Plan for Bangkok.** This provides for the design of a sewage collection and treatment system to serve 3.5 million people. The system will cover an area of 370 sq. km.

Singapore

The Singapore and Kalling Basin catchments cover one-sixth of the total area of Singapore and include about half of Singapore's built-up area.

In 1977, the rivers in these catchments were grossly polluted and supported little or no aquatic life. A programme was initiated in that year to restore the rivers by removing the various sources of pollution.

Pig farms were identified as the greatest source of pollution. There were 610 farms with a total of 75,600 pigs. In addition, open rearing of ducks on 500 farms also contributed to water pollution. Another major source was the 21,000 premises without modern sanitation. These premises were in densely populated squatter colonies with poor accessibility for refuse removal and cleansing work. Some 4900 street hawkers within the catchments also contributed towards water pollution. Riverine activities which included trading, transport, boat building and repairing discharged solid and liquid waste into the rivers.

Several government ministries and agencies were involved in a 10-year programme to clean up the river catchments. The following strategies were adopted:

a) Pig farming was phased out since it was not feasible to treat the pig waste to an acceptable standard;

b) Unsewered premises were either resettled or provided with sewerage facilities. Resettlement was resorted to where the areas were so congested that it was physically impossible to provide sewerage facilities, and where the provision of these facilities alone would not solve the pollution problem;

c) Markets and food centres with proper pollution control facilities were constructed for the relocation of the street hawkers;

d) Duck farms were phased out to make way for public housing development;

e) Lighterage, cargo handling, storage and mooring facilities were extended at Pasir Panjang. Riverine activities such as cargo trading and transport were relocated to this area. Boatyards were required to upgrade their operations to comply with anti-pollution requirements. Small boatyards that were not able to do so were offered alternative sites in Jurong.

More than 90% of the pollution load identified at the start of the clean-up programme has been eliminated. The rivers today are visibly cleaner and much of the malodour that came to be associated with the rivers has been removed. Aquatic life has returned and the rivers can now support a variety of recreational activities. The environment as a whole has improved. Physical improvement works such as dredging, repair of river walls, tiled and landscaped walkways and the creation of sandy beaches help to create a clean and pleasant river environment.

Conclusion

The river pollution control programmes are in various stages of implementation in the South-East Asian countries. These programmes have been carefully drawn up to tackle water pollution at its source through careful planning and the provision of proper pollution control facilities, as well as to mitigate the pollution problems which exist today.

So long as the various governments continue to take measures to safeguard the urban rivers, there is every reason for confidence that our urban rivers will not be destroyed as a result of economic growth and continuing urbanization.

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TOXICITY SCREENING OF OIL DISPERSANTS IN SOUTH-EAST ASIA

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ABSTRACT

A selection of oil dispersants marketed in South-East Asia were tested for their toxicity to fish under tropical ambient temperatures, to identify dispersants with levels of toxicity acceptable for use in oil spill clean-up operations at sea and along shores. The method used was the static acute bioassay test. Tests were conducted on dispersants alone and mixed with a standard light Arabian crude oil, using Tilapia nilotica as a test animal. Results generally indicate considerably higher toxicities for dispersant plus crude oil mixtures when compared with those for dispersant alone. Whilst the United Kingdom toxicity ratings of Jeffery and Nichols (1973) for oil dispersants may not be directly applicable to the present dispersant-oil mixture toxicities, the same ratings may be applied to the toxicity values (48hr LC50) derived from dispersant alone. Of the 9 dispersants tested without mixing with crude oil, Servo CD-2000 and Hydrosol DN-40 were found to be practically non-toxic, and hence may be considered suitable for use in oil spill clean-up in nearshore waters and on shores. The rest of the dispersants were found to be slightly toxic and may be considered for use in the open sea.

Introduction

Oil dispersants are chemical formulations that break up oil slicks into tiny globules, which are easily dispersed in the water column. These globules, being spherical in form, expose maximum surface area to the surrounding marine environment, thereby bringing about accelerated degradation of the oil.

Following the "Torrey Canyon" oil spill of 1967, the development of dispersants to combat oil spills at sea increased, along with research on suitable methods to assess the toxicity of oil dispersants on aquatic life, apart from their physical effectiveness in the dispersal of oil at sea (Blackman et al., 1978; Canevari, 1978; Ward and Parrish, 1982; Wells et al., 1983).

Recent formulations of oil dispersants are claimed to have considerably lower toxicities to marine life, but the quantities used to combat an oil spill at sea can cause significant ecological damage. This is particularly so for organisms at the lower trophic levels, including the sensitive eggs and larval stages of fish, crustaceans and molluscs which form the potential future stocks of a fishery.

The present study is part of a United Nations Environment Programme (UNEP) project for the East Asian Seas, to establish standard procedures for toxicity testing of oil dispersants in the South-East Asian region. It aimed to identify those dispersants currently marketed in the region that are relatively lower in toxicity to marine life, and hence may be considered acceptable for use in oil spill clean-up operations at sea and on shores. The study is a first attempt to determine toxicities of oil dispersants under tropical ambient temperatures. It did not aim at achieving high levels of accuracy in toxicity assessment. What is more important is a convenient and speedy methodology to determine relative toxicities of a range of oil dispersants, and a set of toxicity ratings from the available data.

Methodology

The test method adopted in the present study was the static acute bioassay test (Sprague, 1969; Wilson, 1974), based upon a protocol developed at a regional workshop in Penang, Malaysia, in March 1984, and subsequently revised at at review meeting in Syndey, Australia, in November 1985. The tests were conducted on the dispersant alone and on the dispersant in a 1:1 mixture with a standard Light Arabian Crude Oil (UN 1993, class 3, T. 300 II, flashpoint 21°C).

The dispersants include BP 1100X, BP 1100WD, Chemkleen OSDA-NY, Corexit 8667, Corexit 9527, Diversey OSD, Gold Crew, Hydrosol SE-4, Hydrosol DN-40, Napasco Petro-Solv, Servo CD-2000, Shell LTX and Vans OSD-29 (Table 1). Dispersants that are water dilutable concentrates were prediluted in seawater at 1:10, except for Gold Crew which was diluted at 1:20 following manufacturer's instructions.

Table 1: Oil dispersants - technical data

Dispersant	Specific Gravity	Density	Flash Point (°C)	Kinematic Viscosity (cst)	Solvent Base
BP 1100X	0.82 (20°C)	-	>71(ACC)[1]		CHSB[2]
BP 1100WD[3]	-	0.87g/ml(15.5°C)	87(PMCC)[4]	20.0(21°C)	Nil
Chemkleen OSDA-NY	0.86(25°C)	-	79(PMCC)	8.25(25°C)	Nil
Corexit 8667	0.86(15.6°C)	7.15Lb/Gal(15.6°C)	93(PMCC)	10.0(15.6°C)	CHSB
Corexit 9527[3]	0.998(15.6°C)	0.31Lb/Gal(15.6°C)	93(SCC)[5]	67.0(15.6°C)	Nil
Diversey OSD	0.91(15.6°C)	0.80g/ml(15.6°C)	>74(PMCC)	3.0(20°C)	CHSB
Gold Crew	-	1.04g/ml(0°C)	Nil	35.0(0°C)	Nil
Hydrosol DN-40[3]	0.99(15°C)	-	98(PMCC)	50-70(20°C)	Nil
Hydrosol SE-4	0.90(15°C)	-	80(PMCC)	12.0(20°C)	CHSB
Napasco Petro-solv	1.02(15.6°C)	-	26.7(SCC)	-	CHSB
Servo CD-2000[3]	0.82(20°C)	0.82g/ml(20°C)	72(PMCC)	10.0(20°C)	Nil
Shell LTX	-	0.80g/ml(20°C)	77(PMCC)	3.0(20°C)	CHSB
Vans OSD-29	-	-	-	-	-

[1] Abel Closed Cup
[2] Conventional Hydrocarbon Solvent Base
[3] Water Dilutable Concentrate (WDC)
[4] Pensky-Martens Closed Cup
[5] SETA Closed Cup

The test animal used was a freshwater fish, Tilapia nilotica, acclimated to saltwater conditions at 16 ppt salinity in the laboratory holding tanks. It was found to be the most suitable species for toxicity tests in the South-East Asian region, in view of its availability in large numbers and its ability to withstand captivity in conditioning and test tanks. The size of the fish used in the tests ranged from 30 to 70 mm (0.6-4.0g). The test animals were preconditioned in well-aerated holding tanks for about a week prior to a test. They were fed during this period, but feeding was discontinued 24 hours prior to a test and during the test period.

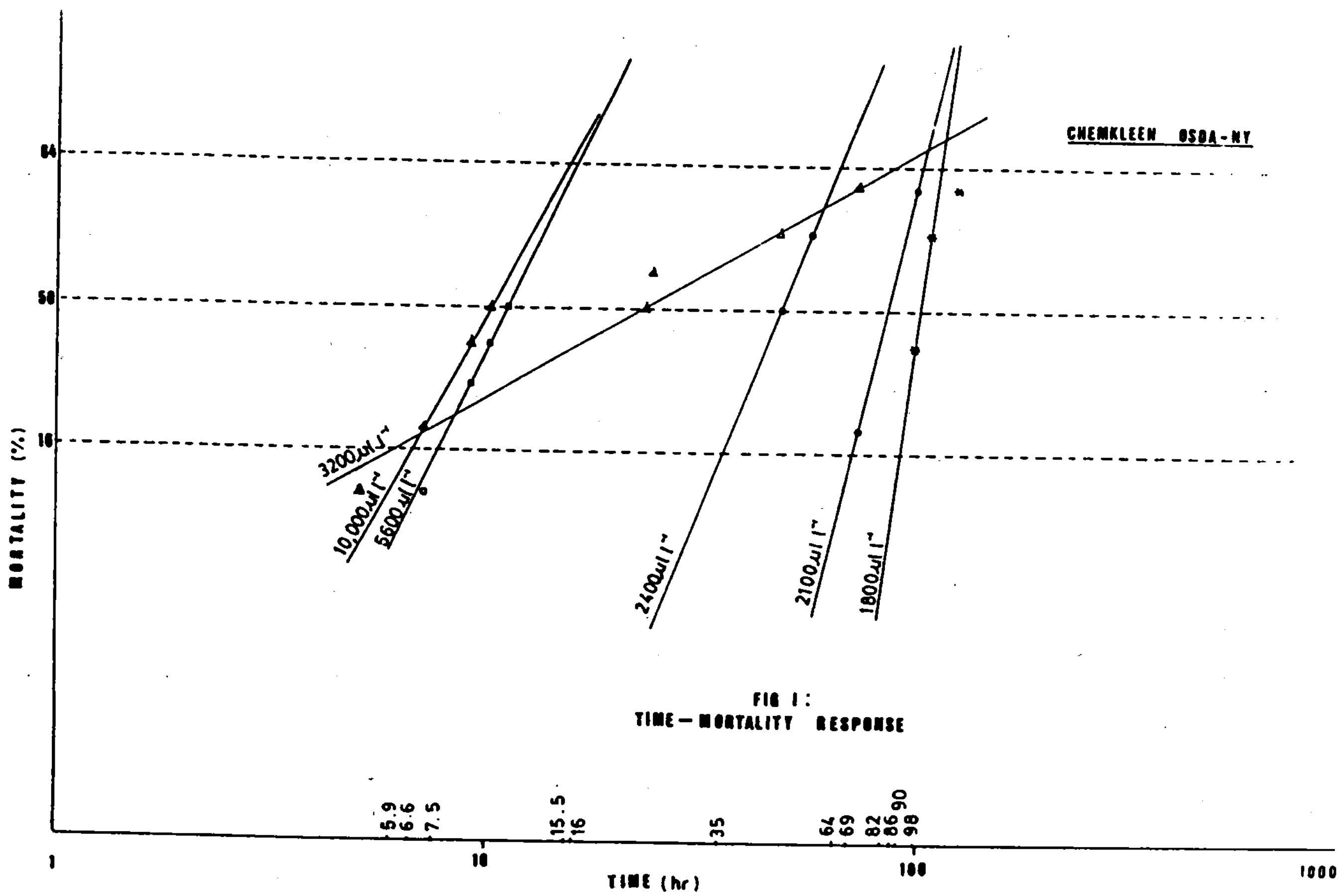
Tests were conducted in glass tanks of 30-litre capacity. The test medium was diluted seawater of salinity 16(±1) ppt, ambient water temperature ranging from 25-30°C (as against ambient air temperature of 28-34°C), and dissolved oxygen exceeding 3 mg/l. There was no aeration of the test media during a test, but the test media were renewed every 24 hours, together with the dispersant tested.

The reference toxicant used was dodecyl sodium sulphate (DSS), to gauge the condition of a new batch of test animals through a 96h LC50 test. The median lethal concentration for 50% of the test animals (LC50) ranged from 1,900-2,400 µg/l.

Each test was conducted on a maximum range of 9 concentrations of the dispersant, selected using the APHA Standard Methods (1980), apart from a "control" and a "reference toxicant". Into each test medium was introduced 10 test animals, at a rate not exceeding 1g of fish per litre of test medium. Tests were carried out long enough to determine 24, 48 and 96h LC50's. A test was rejected when "control" mortality exceeded 10 percent or "reference toxicant" mortality fell outside the range of 30 to 70 percent.

Data were processed to determine LT50 values with 95 percent confidence limits, from a logarithmic time-probit transformation of time-mortality responses (Figure 1). From the LT50 values a toxicity response curve was plotted to determine LC50 values for 24-, 48-, and 96-hour time intervals (Figure 2).

Figure 1: Example of a time-mortality response: Chemkleen OSDA-NY



A rank order test was carried out on the LC50 values for dispersants and dispersant plus crude oil mixtures using the coefficient of correlation (r):

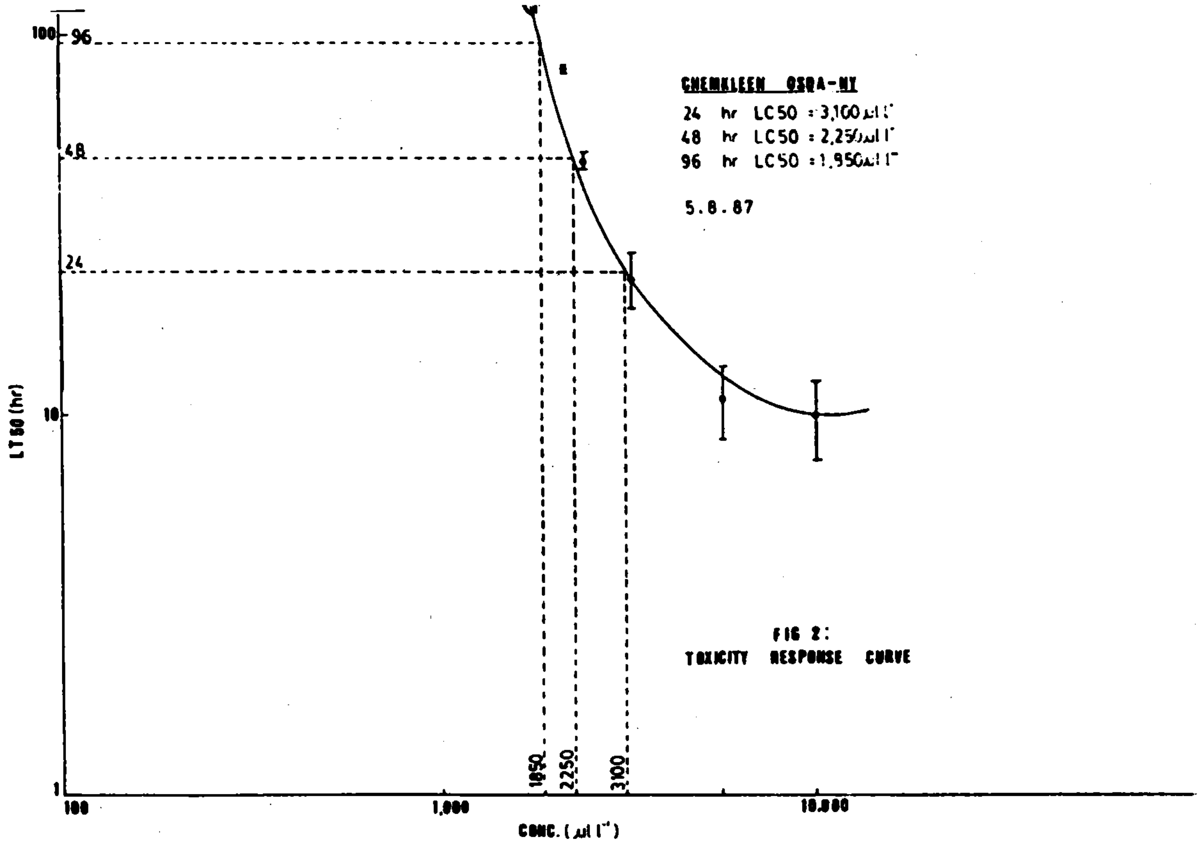
$$\underline{r} = 1 - \frac{6\,(r_1 - r_2)^2}{n(n^2-1)}$$

where r_1 = dispersant rank

r_2 = dispersant plus crude oil rank

n = number of dispersants

Figure 2: Example of toxicity response curve: Chemkleen OSDA-NY



Results and discussion

The results of the toxicity tests on the dispersants and dispersant-plus-oil mixtures are summarized in Table 2. They generally indicate considerably higher toxicities for the dispersant-plus-oil mixtures. A rank order test carried out on the toxicities of both dispersant and dispersant-plus-oil mixture does not show a close agreement between the two (Tables 3A and 3B).

Table 2: Toxicity to *Tilapia nilotica* of oil dispersants and dispersants mixed with a standard light Arabian crude oil[1]

Dispersant	Dispersant (µl/l)			Dispersant + crude oil (µl/l)		
	24h LC50	48h LC50	96h LC50	24h LC50	48h LC50	96h LC50
BP 1100X	9,850	7,200	5,800	-	-	-
BP 1100WD[2]	3,975	3,450	3,025	-	-	-
Chemkleen OSDA-NY	3,400	2,525	2,100	170	123	93
Corexit 8667	2,400	1,500	1,165	2,500	640	250
Corexit 9527[2]	1,750	1,400	1,200	620	445	345
Diversey OSD	-	-	-	99	81	71
Gold Crew[3]	-	-	-	3,050	1,860	1,150
Hydrosol DN-40[2]	62,000	48,500	37,000	89	58	40
Hydrosol SE-4	-	7,800	4,200	-	470	130
Napasco Petro-solv	-	-	-	34	27	23
Servo CD-2000[2]	-	56,000	56,000	6,000	3,400	2,250
Shell LTX	-	10,000	8,700	2,100	1,050	665
Vans OSD-29	-	-	-	45	36	30

1 UN 1993, class 3, T.300 II, flashpoint 21°C for all dispersants tested, except Servo CD-2000 where crude oil used was UN 1267, flashpoint 33°C

2 Concentrates prediluted 1:10 in seawater following manufacturer's instructions

3 Concentrate prediluted 1:20 in seawater following manufacturer's instructions

Table 3A: Rank order of dispersant toxicities based upoh 48h LC50 for Tilapia nilotica

Dispersant	Dispersant 48h LC50 (µl/l)	Rank (r_1)	Dispersant + Oil 48h LC50 (µl/l)	Rank (r_2)	$(r_1-r_2)^2$
Chemkleen OSDA-NY	2,525	5	123	6	1
Corexit 8667	1,500	6	640	3	9
Corexit 9527	1,400	7	445	5	4
Hydrosol DN-40	48,500	2	58	7	25
Hydrosol SE-4	7,800	4	470	4	0
Servo CD-2000	56,000	1	3,400	1	0
Shell LTX	10,000	3	1,050	2	1
				Total	40

Rank order $\underline{r} = 1 - \frac{6 > (r_1-r_2)^2}{n(n^2-1)} = 1 - \frac{240}{336} = \underline{0.29}$

Table 3B: Rank order of dispersant toxicities based upon 96h LC50 for Tilapia nilotica

Dispersant	Dispersant 96h LC50 (µl/l)	Rank (r_1)	Dispersant + Oil 96h LC50 (µl/l)	Rank (r_2)	$(r_1-r_2)^2$
Chemkleen OSDA-NY	2,100	5	93	6	1
Corexit 8667	1,165	6	250	4	4
Corexit 9527	1,200	7	345	3	16
Hydrosol DN-40	37,000	2	40	7	25
Hydrosol SE-4	4,200	4	130	5	1
Servo CD-2000	56,000	1	2,250	1	0
Shell LTX	8,700	3	665	2	1
				Total	48

Rank order $\underline{r} = 1 - \frac{6 > (r_1-r_2)^2}{n(n^2-1)} = 1 - \frac{288}{336} = \underline{0.15}$

Although the test results have been worked out in terms of 24-, 48- and 96-hour LC50's, the 48h LC50 has been retained as the basis for toxicity evaluation in the present study, in view of the condition of the test animals in a confined space and the extremes of tropical ambient temperatures under which the tests were carried out.

The 48h LC50's for dispersants show values ranging from 1,400 µl/l (Corexit 9527) to as low as 56,000 µl/l (Servo CD-2000), whereas for dispersant-plus-oil mixtures values ranged from as high as 27 µl/l (Napasco Petro-Solv) to 3,400 µl/l (Servo CD-2000).

Whilst the United Kingdom toxicity ratings of Jeffery and Nichols (1973) for oil dispersants (Table 4) may not be directly applicable to the present dispersant-plus-oil mixtures, the same ratings appear to be applicable to the toxicity values derived from dispersants alone. Thus from the 9 dispersants tested without mixing with crude oil, Servo CD-2000 and Hydrosol DN-40 may be regarded as "practically non-toxic" to marine life (rating 1) and hence may be considered suitable for use in oil spill clean-up operations in nearshore waters and on shores. The rest of the dispersants (viz.: Shell LTX, Hydrosol SE-4, BP 1100X, BP 1100WD, Chemkleen OSDA-NY, Corexit 8667 and Corexit 9527, in their ascending order of 48h LC50 toxicity) may be regarded as "slightly toxic" (rating 2) and considered for use in breaking up oil slicks in the open sea.

Table 4: Toxicity rating of oil dispersants for the brown shrimp <u>Crangon crangon</u> in the U.K. (from Jeffrey and Nichols, 1973)

48h LC50 (µl/l)	Description	Rating
>10,000	Practically non-toxic	1
10,000 - 1,000	Slightly toxic	2
1,000 - 100	Moderately toxic	3
100 - 10	Toxic	4
<10	Very toxic	5

The screening of oil dispersants for their toxicity is carried out as a regular exercise in some countries of the world, in order to keep track of toxicities of new dispersant formulations entering the market, and to give formal approval to those with minimal toxicities for use in oil spill clean-up operations. Table 5 lists some of these dispersants approved for use in the United Kingdom, the United States of America and France.

Table 5: Some dispersants approved for use in U.K., U.S.A. and France

Dispersant	Approval Source
BP 1100 - X BP 1100 - WD Chemkleen OSDA-NY Corexit 9527 Diversey OSD Servo CD-2000 Shell LTX	Warren Spring Laboratory, U.K., and Ministry of Agriculture, Fisheries and Food (MAFF), U.K., under the Food & Environment Protection Act 1985
Corexit 8667 Corexit 9527 Gold Crew	U.S. Environmental Protection Agency (EPA)
Hydrosol DN-40 Hydrosol SE-4	French Ministry of Environment

Conclusion

The static acute bioassay test to determine the toxicity of oil dispersants, as adopted in the present study, has been found to be a convenient method for the rapid assessment of the relative toxicities of oil dispersants.

The toxicity ratings for oil dispersants, as established in the United Kingdom, have been found to be applicable especially to the present test data for 48h LC50. This would suggest that future tests may be conducted on dispersants alone and evaluations made based upon 48h LC50 values.

The present study has shown that from the range of dispersants tested for their toxicity, 2 dispersants, Servo CD-2000 and Hydrosol DN-40, are practically non-toxic to marine life and hence may be considered for use in oil spill clean-up operations in the inshore coastal waters of South-East Asia.

It is of course desirable that regular screening tests be carried out on oil dispersants, especially in countries that frequently face the problem of oil spills in their coastal waters. The South-East Asian area is no exception to the rule.

Acknowledgement

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OIL SPILL TRAJECTORIES AND CONTROL IN SOUTH-EAST ASIA WITH SPECIAL REFERENCE TO INDONESIAN WATERS

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ABSTRACT

The patterns and spatial distribution of currents affect the possible trajectories of oil spills under the influence of ocean hydrodynamics and especially surface water flows in certain areas. Simple techniques have been developed to model oil spill trajectories in the Cilacap area of Indonesia, using wind, current and tidal data. This study can serve as an example for other countries, in the framework of ASEAN regional research programmes, to meet requirements for the future formulation of guidelines for oil spill control and and clean-up countermeasures.

Introduction

Oil spills can have serious economic impacts on coastal activities and on those who exploit the resources of the sea. More than ten years ago, the oil tanker "Showa Maru" grounded in the Malacca-Singapore Straits, releasing some 5,000 tons of crude oil, and several similar accidents have since occurred in the waters of South-East Asia. Although precautions have been taken to prevent further such accidents in the region, the fact is that accidents are difficult to prevent. With the increasing number of ships passing through South-East Asian waters, particularly through sea lanes located in the waters of ASEAN member countries, it becomes imperative to give a high priority to activities like oil spill trajectory projection and control within the framework of an overall oil spill contingency plan.

Although efforts are being made to combat and control oil spills, there is still a limited capability to handle oil spills in the East Asian Region.

Indonesia, together with the governments of the South-East Asian countries in COBSEA, has conducted several activities with the support of UNEP in implementation of the East Asian Seas Action Plan. Specific activities related to oil pollution control have included:

--- implementation of a technical and scientific support programme for oil spill contingency planning;
--- survey of sources and monitoring of oil pollution; and
--- co-operative study on oil and oil dispersant toxicity testing.

Marine environmental protection

In addition to the abundant petroleum resources exploited extensively in the region, the seas bordering the ASEAN countries are richly endowed with many other marine resources. The marine environment and related ecosystems support diverse species of flora and fauna. The coastal areas and islands are attractive for public amenities and tourist development. The ASEAN region not only has similar marine environments which exhibit broad geomorphological, climatic, biological and physical oceanographic similarities, but it also has similar marine environmental problems which may accumulate or be self-reinforcing across the region. The general oceanographic characteristics of the region have been summarized by Soegiarto (1985).

Recognizing that (oil) pollution knows no natural or political boundaries, especially in the flux of the marine environment from which most of the ASEAN oil and gas is currently produced, ASEAN member countries have been emphasizing the need for close co-operation in the protection and conservation of the environment, in pollution control, and in the safety of petroleum operations. This need is felt particularly strongly because of the geographic proximity of neighboring states, the similar characteristics of their coastal and marine environment with common ecosystems, and a shared interest in sustaining its life support systems.

The Archipelagic State of Indonesia, situated between longitude 94°45'E and 141°05'E, and from latitude 06°08'N to 11°05'S, stretches 5,110 km from west to east and 1,888 km from north to south, consisting of 17,508 islands, over one half of which are unnamed. Approximately two-thirds of the country is covered by tropical oceans, with a total area of 5.8 million sq. km, which consists of 0.3 million sq. km of territorial sea, 2.8 million sq. km of archipelagic waters (perairan Nusantara) and 2.7 million sq. km of exclusive economic zone. The length of the coastline is about 81,000 km.

The Indonesian waters have been an important source of food and economic welfare for the people for centuries due to the rich an diversified life and resources they contain, including minerals and hydrocarbon resources in the shallow seas, and living and other non-living resources in the marine and coastal environment. These waters also sustain other types of activities such as inter-island, regional and international trade, communications, recreation and tourism. Unfortunately, as a result of the rapid economic development of the country in almost all sectors, the marine and coastal resources have been subject to severe direct and indirect pressures.

Of concern are the increasing number of incidents of pollution, the environmental degradation of certain coastal areas and ecosystems, and the destruction of coral reefs. The evaluation of these problems and the implementation of solutions are being carried out in accordance with the Republic of Indonesia Act No. 4 of 1982 concerning Basic Provisions for the Management of the Living Environment. In part the act states that management of the living environment should be based upon the maintenance of the capability of a harmonious and balanced environment to support continued development for the improvement of human welfare.

Oil spill trajectory studies in ASEAN countries

When a major oil spill occurs, it is important to predict the movement of the oil slick and to know where it will end up, especially when resources to combat the oil spill are limited and there are large sensitive areas which need to be protected against the slick.

Malaysia. Most of the coastal resources in Malaysia which are particularly vulnerable in the context of an oil spill have been more or less identified and located. With limited resources and extremely long coastlines, Malaysia is having difficulties in prioritizing these areas for protection when there is a major oil spill. Oil trajectory modelling may be of invaluable assistance in this regard where speed of response is of the essence. Apparently, there is computer software available for modification; however the lack of the required current, tidal and wind data is the main reason for the lack of development in this field.

Thailand will soon be completing and implementing an Oil Spill Contingency Plan, including oil spill trajectory modelling, with technical assistance from the Danish government, and this hopefully will help protect the environment and natural resources in Thai waters. It also will be part of the ASEAN Contingency Plan and thus will ensure effective co-operation among member countries in their efforts to safeguard international waters from the danger of oil pollution.

Philippines. With all the advances that have occurred in the field of oil spill control and containment technology, and the growing awareness of the need to protect the environment, it is imperative that the Oil Spill Contingency Plan (including oil spill trajectory modelling) as well as the regulatory system governing the control of marine pollution, be upgraded not only in terms of logistics and efficiency but, more importantly, in consideration of such issues as the environmental consequences of offshore oil operations and trans-frontier oil spills. It is through strengthening and furthering the efforts of the ASEAN regional bodies that sensitive trans-frontier oil pollution issues can be addressed.

Oil spill trajectories and control in Indonesia

In **Indonesia**, an oil spill trajectory modelling capability and the related software have been available to oil contractors for several years. Oil spill tracking techniques were used, for example, following the blow-out of an oil well in East Kalimantan in 1985. However, as already noted in the case of Malaysia, there is a lack of reliable data on climatology and the hydrodynamics of ocean waters for this purpose. Thus in the course of oil spill tracking, some efforts have been made in Indonesia to support oil spill contingency planning and its related activities.

Currents and water circulation in Indonesian waters generally follow the topographic configuration of the sea bottom, while local conditions can influence the general flow in certain areas. For example, in open waters, the tidal currents are generally weak and merely strengthen or reduce the currents caused by monsoonal winds. However, in coastal areas off river mouths and in comparatively narrow passages such as the straits between islands, tidal currents are of considerable importance. In the area of East Sumatra in the Malacca Straits, for instance, water masses or fronts caused by coastal configurations affect tidal currents. Another phenomenon observed in the coastal waters of East Sumatra is the hydrodynamic process of wave refraction and resulting surf and currents. Longshore and rip currents caused by wave-generated mass transport to and from the shore and along the coastline have also been observed.

Oil spill trajectories can be estimated by vector addition of the surface current and wind components, and these calculations can be aided by computer programmes. Trajectory studies have been carried out to support the development of an oil spill contingency plan at Cilacap on the south coast of Java in the area next to the state-owned Pertamina oil refinery. The waters around Cilacap form a tidal creek and the tidal mechanism is relatively easy to observe (Figures 1 and 2) during the prevailing winds from the south or from the Indian Ocean to the north. It was assumed that the oil spill trajectory at the sea surface will be influenced mainly by the velocity and direction of the wind and by the current at the sea surface, since other parameters such as wave and oil characteristics will also follow the wind and surface current system. Wind and current measurements for this purpose were conducted in the Cilacap area by the survey team, and the simulation model took into account possible changes in space and time for the winds and surface currents. Using this approach, the trajectory and control of the oil spill over time was projected on a co-ordinate system.

In general, three types of environmental pollution modelling systems exist for the marine environment: the dispersion model, the reaction model and the marine hydrodynamic model. In the Cilacap study, the hydrodynamic model was used to simulate oil spill trajectories and control.

Basic equations

The following equations were used to construct a simple simulation model for oil spill trajectories.

a) An oil spill trajectory under the influence of **wind** follows the relationship:

$$V_d = 0.033\ V_{sw}$$

where: V_d = oil drift

V_{sw} = wind speed ± 10 m above sea surface

The interrelationship of oil drift and wind speed will differ according to the geographical situation of the area; according to some observations, the oil drift is between 2.5 and 4.2% of the wind speed.

The time span for the oil spill trajectory follows the relationship:

$$T = \frac{D}{0.033\ V_{wp}\ P_{wr}}$$

where: T = time for the oil to drift the distance D

V_{wp} = resultant of the mean wind speed or mean wind speed

P_{wr} = resultant of the wind during a certain period or total wind percentage

b) An oil spill trajectory under the influence of **currents,** where the average current speed, average direction and percentage of currents during a certain period are known, follows the relationship:

$$T_{cm} = \frac{D}{V_{cp}\ P_{cp}} = \frac{D}{V_{cd}}$$

where: T_{cm} = time for the oil to drift the distance D

V_{cp} = average current speed

P_{cp} = total percentage of currents in a certain period

V_{cd} = oil spill drift on the sea surface

c) Consequently, the parameters of the oil spill trajectory under the combined influences of **wind and current** were calculated as follows:

$$V_{wc} = 0.033\ V_w + 0.56\ V_c$$

Note that the influences of wind and current are not always of the same duration, and therefore:

$$P_{wc} = 0.5\ (P_w + P_c)$$

In this case, the time required for the oil spill to travel a distance D will be:

$$T_{wc} = \frac{D}{V_{wc}\ P_{wc}} = \frac{D}{V_{wcd}}$$

where: T_{wc} = time required to travel the distance D

V_{wc} = resultant of the wind and current speeds

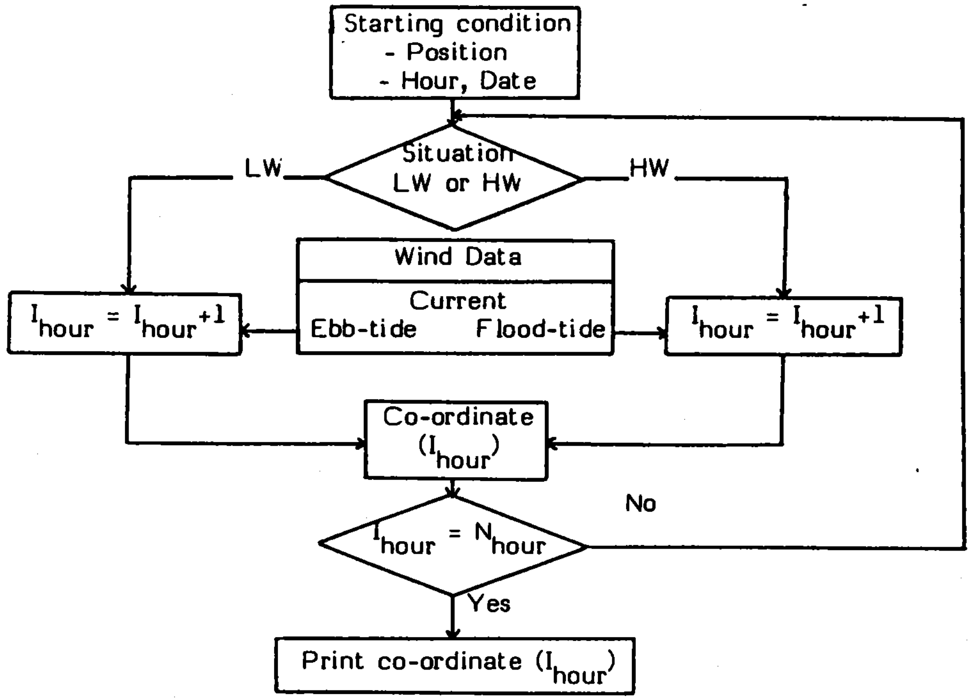
P_{wc} = mean percentage occurrence of wind and current

V_{wcd} = oil spill trajectory under the influence of wind and current

d) The oil spill trajectory can be plotted in a simple X - Y co-ordinate system with the wind and current vectors added to give the resultant trajectory vector.

e) The simulation model used to calculate oil spill trajectories in the Cilacap area using data collected over a 6 month simultaneous investigation of oceanographic and meteorological parameters is shown schematically in Figure 3.

Figure 3: Schematic simulation model for oil spill trajectory predictions



As is clear from the above example used for oil spill trajectory modelling in the Cilacap area, it is necessary to have as the starting condition the **geographic position** of the oil spill in order to relate it to the available data for the specific area to be dealt with, as well as the **time and date** to obtain tidal data from existing tide tables for the area concerned. The model can be iterated on an hourly basis to obtain the desired cumulative movement of the oil spill. The model was tested for Cilacap by simulating spills at three different locations, giving the results shown in Figures 4, 5 and 6. The results showed that out-going currents on the ebb tide had more influence than in-coming currents on the flood tide. This was also true for wind speed and direction, while depth and coastal configuration also had an effect.

The model is now being extended with more primary data to allow the inclusion of seasonal changes for at least a whole year, prior to starting similar modelling of other semi-enclosed basins such as Jakarta Bay. This process will thus support the development of contingency plans, and later assist in the formulation of guidelines for oil-spill control and clean-up countermeasures.

Conclusions

Simple modelling of oil spill trajectories and their control, starting with primary wind and tidal data, is proving beneficial in supporting oil spill contingency planning.

With the limited data and extremely long coastlines generally found in ASEAN countries, oil spill trajectory modelling represents a valuable initiative in the framework of ASEAN regional research programmes for marine environmental protection.

Despite the simplicity of the model involved and its relatively simple data requirements, such models appear to lend themselves to actual operational oil spill trajectory and control problems once the necessary wind and tidal current observations have been accumulated for a given area.

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Figure 1: Incoming tidal currents in Cilacap area

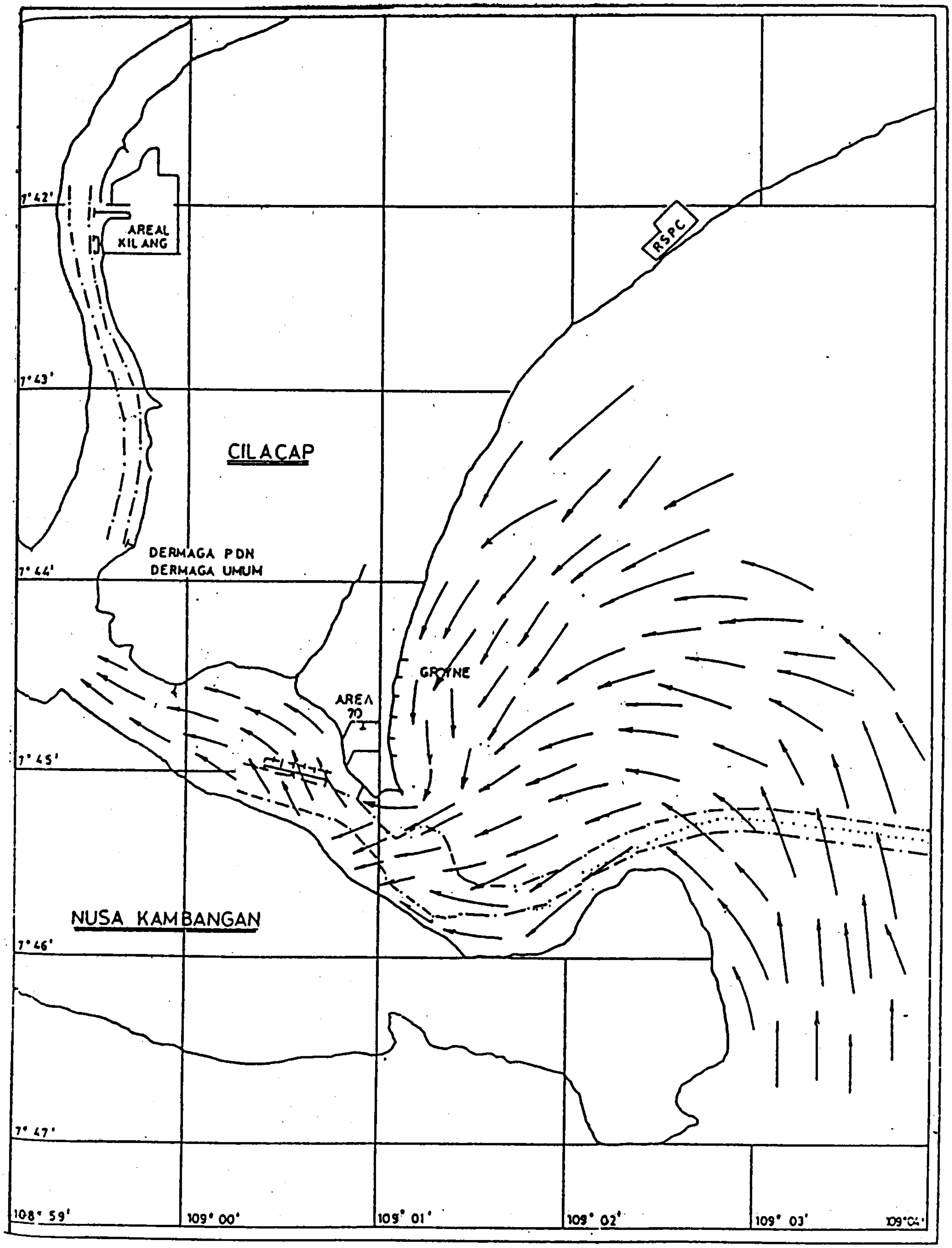


Figure 2: Outgoing tidal currents in Cilacap area

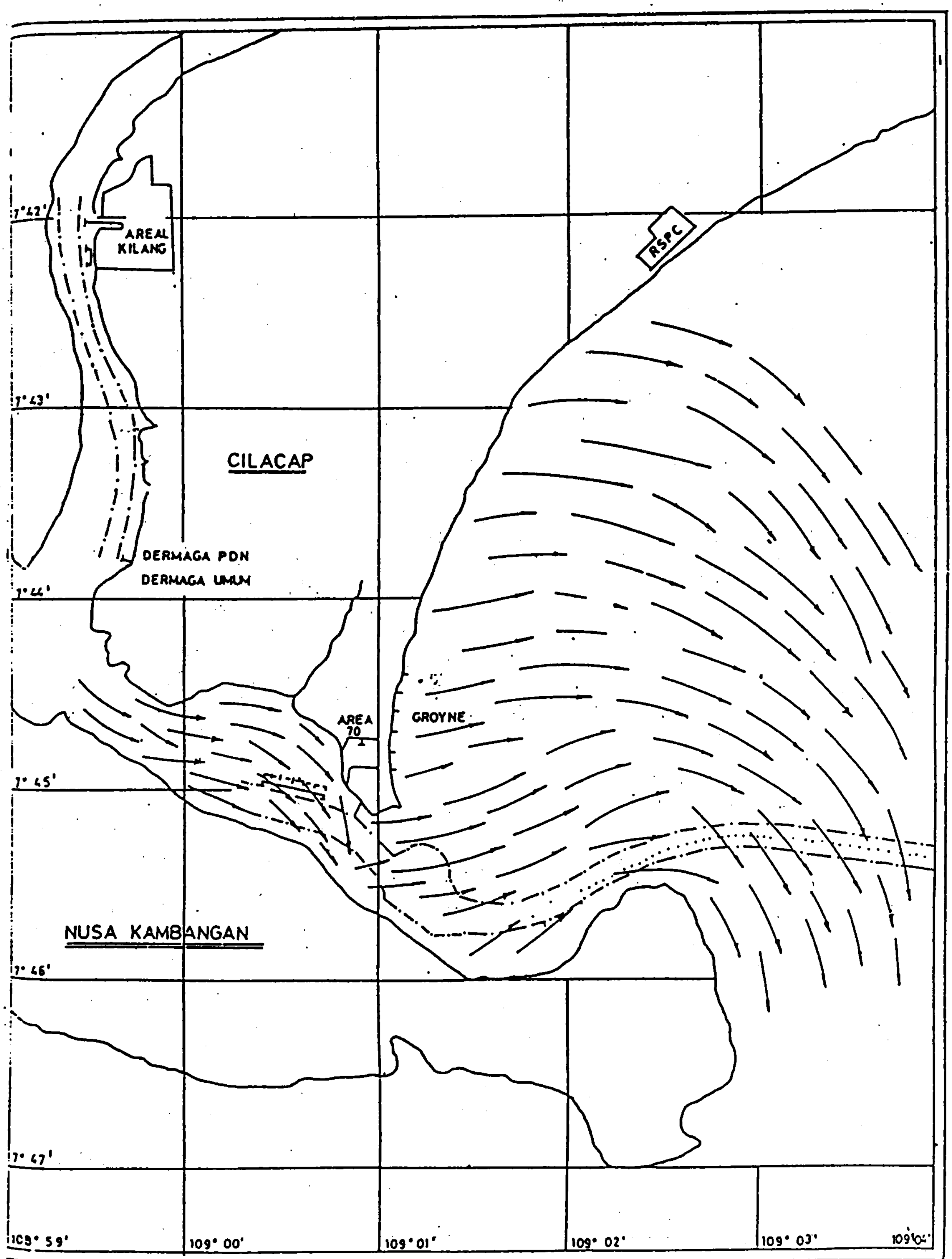


Figure 4: Simulated oil spill trajectories - release from CIB Station

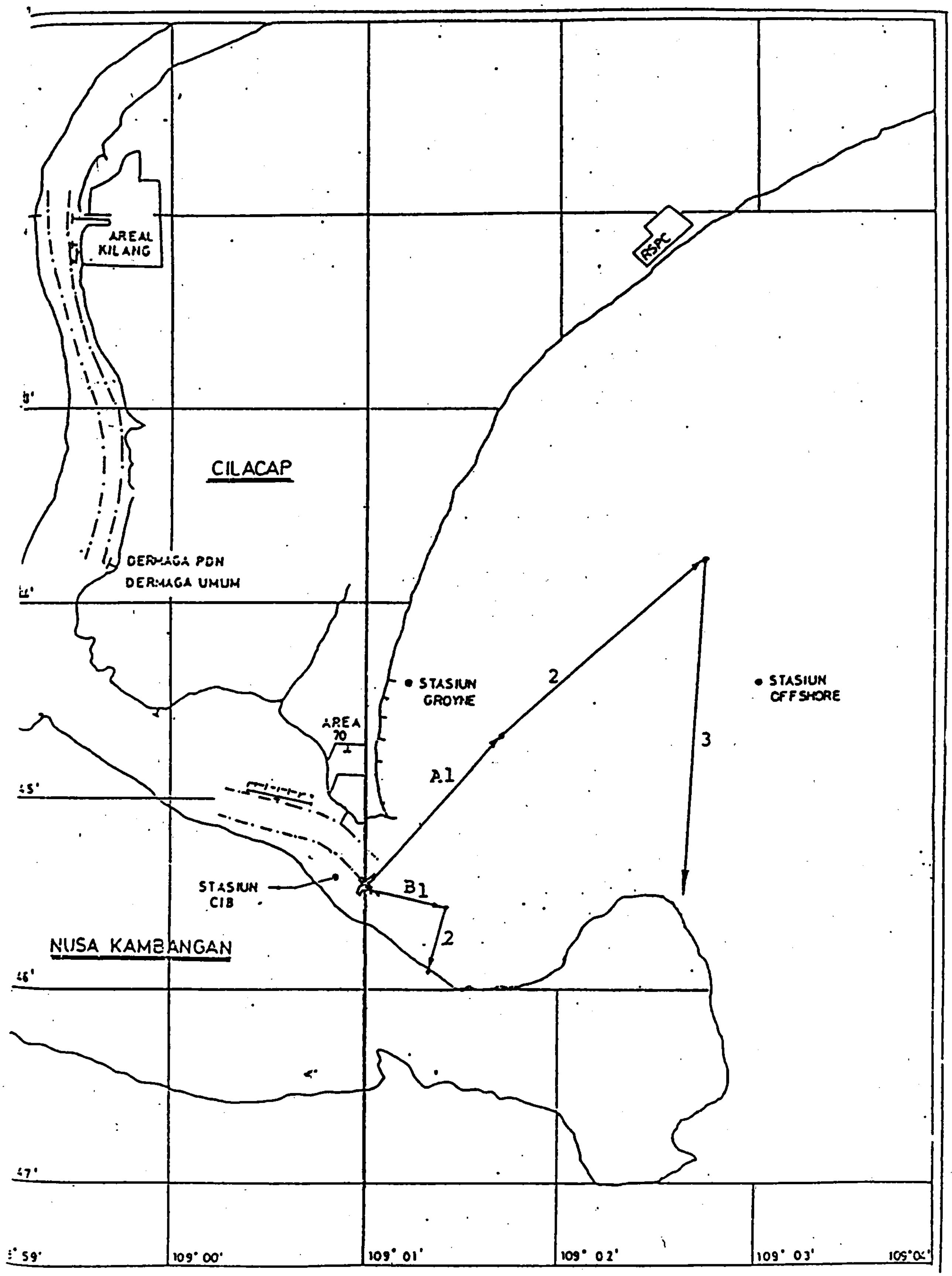


Figure 5: Simulated oil spill trajectories - release from offshore station

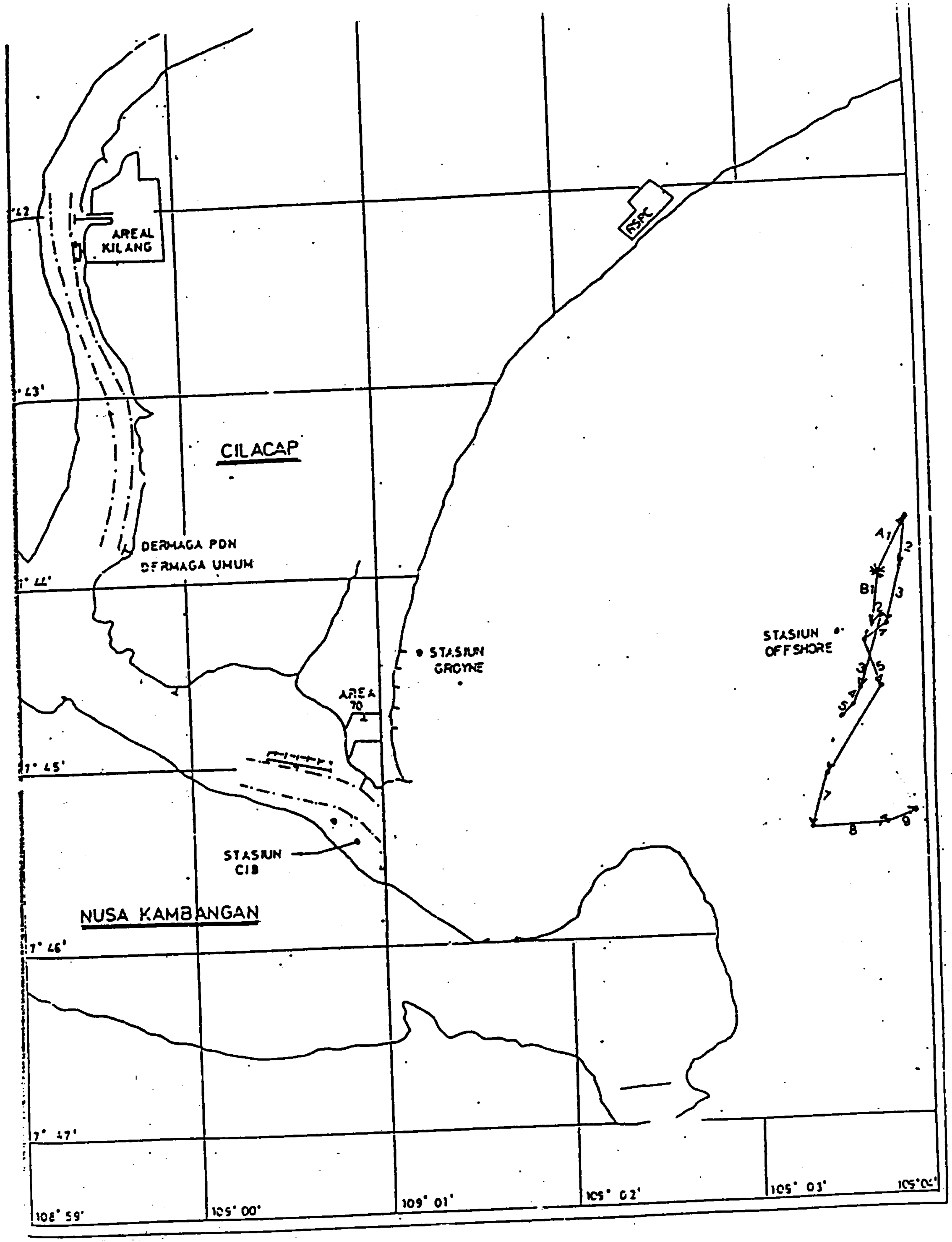
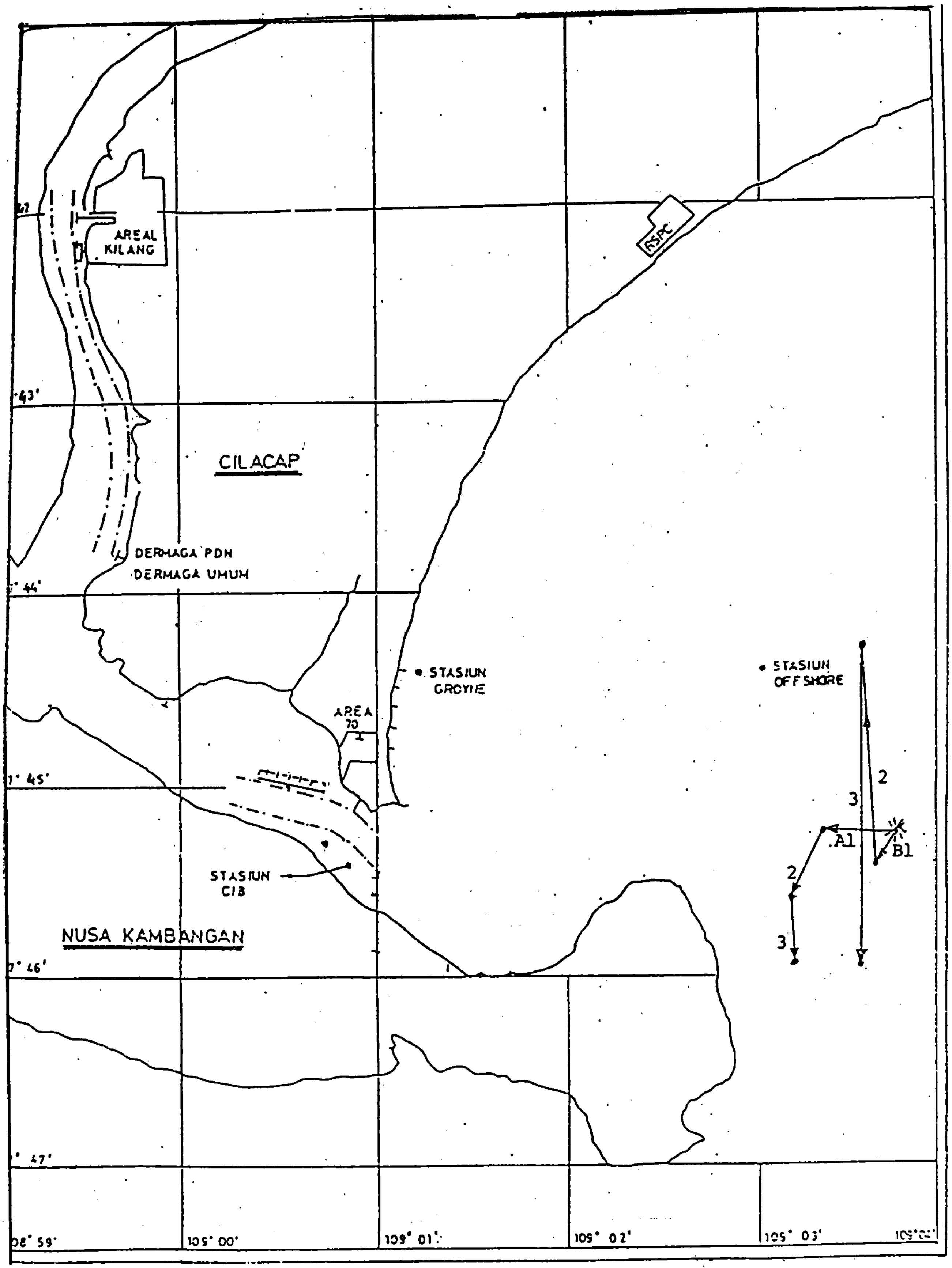


Figure 6: Simulated oil spill trajectories - release from tanker anchorage



ACHIEVEMENTS IN THE DEVELOPMENT OF THE ACTION PLAN FOR THE PROTECTION OF THE MARINE ENVIRONMENT AND COASTAL AREAS OF THE SOUTH-EAST PACIFIC

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ABSTRACT

The operative phase of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific began in 1984, with the participation of 16 marine research laboratories from Colombia, Chile, Ecuador, Panama and Peru in co-ordinated programmes of pollution research and monitoring in the South-East Pacific (CONPACSE), and in the implementation of a regional contingency plan to control oil spills. The number of institutions participating in the plan increased to 42 by 1987, with 26 CONPACSE institutions studying 22 areas of the 27 selected initially in 1983. At present, CONPACSE has gathered basic information on the regional distribution of dispersed/dissolved petroleum hydrocarbons, the occurrence of tar on marine shorelines, and the content of heavy metals in organisms and sediments, as well as an up-to-date inventory of the main land-based sources of pollution.

In 1983, a Trust Fund was established to support the activities of the plan. By 1986, 65% of the assessed contributions were collected; 35% supported institutional participation, and the remainder was used for nine courses, seminars, exercises and workshops organized since the beginning of the operative phase. A total of 25 regional activities were undertaken, plus 7 more scheduled for 1987. The four legal instruments making up the legal framework of the Action Plan have been ratified and have come into force. Phase II of CONPACSE begins with two main components: monitoring of marine pollution, and coastal environmental planning in the South-East Pacific.

This paper describes the achievements in the development and implementation of the Action Plan from 1981 to the present.

Background

In 1977, the Permanent Commission for the South Pacific (Comision Permanente del Pacifico Sur, CPPS) approached the United Nations Environment Programme (UNEP) for assistance in the preparation of a regional action plan to combat marine pollution. The request was based on the results of the first inventory of pollution sources in Chile, Ecuador and Peru performed in 1975 with the support of FAO. This was followed by the CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution of the South Pacific, held in Santiago, Chile, in November, 1978. The following year, the Governing Council of UNEP approved the inclusion of the South-East Pacific in the UNEP Regional Seas Programme.

The plenipotentiary representatives of the Governments of Colombia, Chile, Ecuador, Panama and Peru adopted the South-East Pacific Action Plan in Lima, Peru, in 1981 (CPPS/UNEP, 1983), and at the same time agreed to a Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (UNEP, 1984). They also agreed on regional co-operation to combat pollution of the South-East Pacific by petroleum hydrocarbons and other noxious substances in cases of emergency. The meeting appointed the CPPS as Regional Co-ordinating Unit (RCU) for the Action Plan and as depository for the Convention. The characteristics and early development of the action plan have been described by Arriaga (1985).

Achievements of the South-East Pacific Action Plan

Development of the environmental assessment component

To assess the current conditions of the marine environment and coastal areas of the South-East Pacific, the First Intergovernmental Meeting on the Action Plan, held in Quito, Ecuador, in July, 1983, approved two basic programmes in CONPACSE:

--- Research, monitoring and control of pollution of the South-East Pacific by petroleum hydrocarbons, and its effect on marine communities in ecologically sensitive areas of the South Pacific; and

--- Characterization and monitoring programme for pollution of the South-East Pacific from domestic, agricultural, industrial and mining sources, and evaluation of its effects on marine organisms.

Working documents were prepared for the above programmes establishing the minimum work plan necessary for their execution, and recommending techniques and methods (UNEP/CPPS, 1983a-c, 1984a-e).

Starting in late 1984, studies were begun on the following aspects of CONPACSE:

--- Inventory and characterization of marine pollution sources in the South-East Pacific;

--- Identification of heavy metals and pesticides in organisms, sediments and waters of special interest in the South-East Pacific;

--- Identification of dispersed/dissolved petroleum hydrocarbons in seawater, with related oceanographic parameters;

--- Estimates of polluting discharges from the main pollution sources in the South-East Pacific;

--- Research on oil pollution effects on marine communities;

--- Laboratory studies of pollution effects on marine organisms from the South-East Pacific;

--- Identification of tar balls on shores;

--- Identification of petroleum hydrocarbons in marine organisms and sediments in the South-East Pacific;

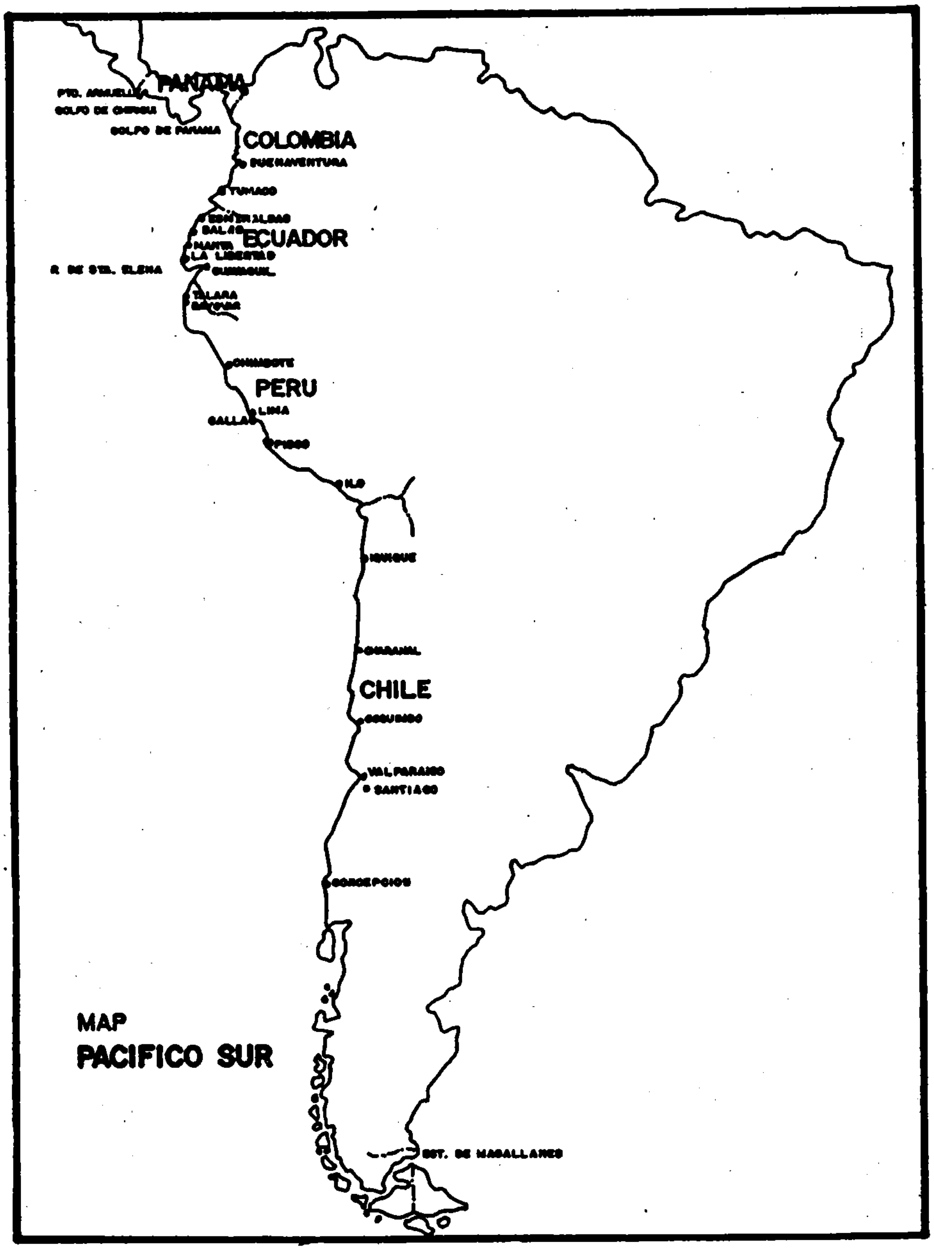
--- Identification of critical areas, vulnerable resources and protection priorities against oil pollution in the South-East Pacific;

--- Intercalibration exercises and intercomparisons for heavy metals, pesticides and petroleum hydrocarbons in seawater, sediments and marine organisms;

--- Estimates of microbiological pollution in coastal waters and along shores in some areas of particular interest in the South-East Pacific.

At first, these research studies concentrated on 12 of the 27 geographical areas of particular interest selected by member governments in 1983. The number of areas subject to CONPACSE research studies increased to 22 by 1985-86, representing 81% of the total areas selected. It is expected that all of the areas selected will be included in the programme by 1988. Figure 1 shows those areas where CONPACSE research studies have been concentrated. As of May, 1987, 42 regional institutions have directly participated in these programmes, and the results have been collected in 40 advanced technical reports.

Figure 1: Areas of the South-East Pacific covered by CONPACSE Phase 1



Broadly speaking, these results can be summarized as follows:

--- Several areas in the region suffer from serious pollution problems, including: Valparaiso Bay and Concepcion Bay in Chile; Buenaventura Bay at Tumaco, Colombia; the Gulf of Guayaquil, Ecuador; Panama Bay, Panama; and the metropolitan areas of Lima and Callao, Peru.

--- As a result of the discharge of domestic sewage, high coliform concentrations have been found in several coastal areas of the South-East Pacific.

--- Heavy metals and pesticides have been found in variable concentrations in sediments and in benthic organisms from some areas of Panama, Chile and Peru. The results obtained so far suggest an increase in these pollutants.

--- Pollution by petroleum hydrocarbons is restricted to few areas of the South-East Pacific. In Panama, it is confined to the entrance to the Panama Canal, with higher concentrations of dispersed/dissolved hydrocarbons in the Port of Balboa. As far as Ecuador is concerned, concentrations seem to diminish from the coast towards the sea, with higher concentrations found in the inner estuary of the Gulf of Guayaquil. In Peru, oil pollution seems to be confined to the metropolitan areas of Lima and Callao.

The Third Extraordinary Intergovernmental Meeting on the South-East Pacific Action Plan, held in Bogota, Colombia, April 27-29, 1987, approved the extension of the CONPACSE Phase I programme until 1988 to allow time to complete the research evaluating the pollution in those areas still to be included in the programme. The extension will also be used to design CONPACSE Phase II, which will roughly consist of the formulation and maintenance of the pollution monitoring programme in the South-East Pacific, and the design and implementation of an environmental management programme and planning.

Development of the environmental management component

Two environmental management activities have been implemented alongside the pollution research and evaluation activities. One implements Article 8 of the Lima Convention concerning environmental impact assessment; the other implements the Regional Contingency Plan for Control of Oil Spills in the South-East Pacific, in accordance with the Regional Co-operation Agreement and its supplementary protocol.

Environmental impact assessment

The activities carried out included the preparation of two regional case studies and their evaluation, as well as the design and implementation of a course on Basic Techniques for Environmental Impact Assessment. The work involved in the implementation of these activities contributed to the development of this concept throughout the region. 110 experts from Colombia, Chile, Ecuador, Panama and Peru have taken part in these activities from November 1983 through November 1986, and the participation of 25 additional experts is expected in 1987.

The following activities have been carried out:

--- CPPS/UNEP/ECLAC Workshop-Seminar on Environmental Impact Assessment in the Marine Environment and Coastal Areas of the South-East Pacific, Santiago, Chile, November, 1983. This seminar analysed the current status of EIA in the region and laid the groundwork for the development of more specific activities on the applicability of this concept in the region.

--- Second Meeting of the 23rd GESAMP Group on Environmental Impact Assessment, Bangkok, Thailand, 1984. Two experts from Chile attended this meeting on behalf of the South-East Pacific region. Their concern was to acquire experience in assessment techniques which would help them in the preparation of a detailed regional case study incorporating the concepts of assimilation capacity, boundary conditions, etc.

--- CPPS/UNEP/ECLAC Workshop on the Assessment of the Environmental Impact on the Marine Environment of Potentially Noxious Substances from Coastal Sources. A Case Study in Chile: Concepcion. December 1984. Thirty-five experts from member countries analysed the effects of toxic discharges drained by the Bio-Bio River into the Arauco Gulf and Concepcion Bay. The project used guidelines recommended by UNEP to GESAMP Working Group 23 on Environmental Impact Assessment. The experts evaluated these guidelines for their applicability at the regional level.

--- Case Study on the Environmental Impact Assessment of Harbour Development: the Port of Guayaquil, Ecuador. CPPS/UNEP/ECLAC, January-November 1986. Two consultants, assisted by 15 Ecuadorian institutions, prepared a detailed case study using environmental impact matrices to collect, select and evaluate information on the ecological effects on the estuarine system attributed to the development of the Port of Guayaquil. The results of the case study were discussed in a Workshop in November, 1986, at which 54 experts analysed the environmental effects and the methodology used using the Delphi method and evaluation matrices. The workshop made recommendations to the Extraordinary Intergovernmental Meeting on the Action Plan, April, 1987.

To ensure that objectives are achieved and to improve the quality of research, CONPACSE stresses the development of training activities such as workshops, courses and seminars. Thus, between 1981 and 1986, 332 experts from countries participating in the Action Plan have received training through their attendance at 16 courses and other educational activities organized within the framework of the action plan. During 1987, 115 additional experts will be trained in six different fields of study. Table 1 lists training activities from 1981 to 1987.

--- CPPS/UNEP/ECO(PAHO) Regional Course in Basic Techniques and Methods for Environmental Impact Assessment, Guayaquil, Ecuador, December, 1987. The implementation of this course responds to one of the recommendations of the two previous workshops analysing detailed case studies. The Pan-American Human Ecology and Health Centre of the Pan-American Health Organization (PAHO) designed the course at the request of the CPPS and with the support of UNEP. It covers the use of basic techniques for environmental impact assessment: matrices, trial listings, slides, etc., including definitions, concepts and shortcomings. The course is directed to professionals in charge of environmental management in the region.

The Extraordinary Intergovernmental Meeting (Bogota, April, 1987) adopted the experts' recommendation that the CPPS, in consultation with UNEP and member governments, should prepare a **Protocol on Environmental Impact Assessment** as part of the future work plan.

Regional Contingency Plan to Combat Pollution of the South-East Pacific from Petroleum Hydrocarbons and other Noxious Substances in Cases of Emergency

In July, 1983, the First Intergovernmental Meeting on the Action Plan approved the Regional Contingency Plan, one of the few in the world, to facilitate regional co-operation in the fight against accidental oil pollution, thus implementing the Agreement on Regional Co-operation and its complementary Protocol.

Some 108 national experts have been involved in the design and development of the Regional Contingency Plan. These experts have been trained through three oil spill control courses held in 1981, 1985 and 1986 (see Table 1).

The development and implementation of the Regional Contingency Plan have produced the following results:

--- An up-to-date report has been prepared on equipment available in the region to control oil spills.

--- A list has been maintained of the names of national experts whose assistance could be sought in cases of accidental oil pollution.

--- The critical areas, vulnerable resources and protection priorities against accidental oil pollution in the South-East Pacific have been identified.

--- A proposal has been formulated for the standardization of codes for regional communications within the framework of the Contingency Plan.

--- Work has started on guidelines for economic appraisal of ecological damage due to accidental oil pollution.

--- Member Governments have been supported to design and develop their own national contingency plans.

Table 1: Training activities supporting the South-East Pacific Action Plan, 1981-1987

Title	No. of National Experts Attending
CPPS/UNEP/IMO Regional Course on Oil Spill Control, Vina del Mar, Chile, April, 1981	30
Workshop on Legal Practices for the Protection of the Marine Environment Bogota, Colombia, May, 1981	26
XV Pacific Science Congress, Dunedin, New Zealand, February, 1983	5
Earthscan Media Seminar, Cartagena, Colombia, March, 1983	5
Workshop on Standardization of Pollution Monitoring Methods for Petroleum Hydrocarbons and Pesticides in the South-East Pacific, Callao, Peru, July, 1983	17
Workshop on Environmental Impact Assessment in the Marine Environment and Coastal Areas of the South-East Pacific, Santiago, Chile, November, 1983	19
VIII Latin American Congress on Biological Oceanography, Montevideo, Uruguay November-December, 1983	6
Second Meeting of GESAMP Working Group 23 on Environmental Impact Assessment, Bangkok, Thailand, October-November, 1984	2
CPPS/UNEP/ECLAC Workshop on Environmental Impact Assessment of Potentially Noxious Substances from Coastal Sources in the Marine Environment: A Case Study, Concepcion, Chile, December, 1984	35
CPPS/UNEP/IMO Simulation Exercise in Oil Spill Control, Panama City, Panama, March, 1985	30
First Latin American Congress on Biological Oceanography, Santa Marta, Colombia, November, 1985	5
Intercalibration exercise for petroleum hydrocarbons dissolved/dispersed in seawater, February, 1986.	6
CPPS/UNEP/ECO-CEPIS(PAHO) Course on Rapid Assessment of Pollution Sources in the South-East Pacific, Lima, Peru, August, 1986	32
Training Course on Oil Spill Control Contingency Planning in the South-East Pacific, Valparaiso, Chile, September, 1986	56
Workshop on Environmental Impact Assessment of a Harbour Development: A Case Study, Guayaquil, Ecuador, November, 1986	54
IOC/IOCARIBE/CPPS/UNEP Course on Analytical Techniques for the Identification of Petroleum Hydrocarbons in Marine Organisms and Sediments, Puerto Morales, Mexico, November, 1986.	4
Expert Meeting to Review Maps of Critical Areas, Vulnerable Resources, and Protection Priorities from Marine Oil Pollution in the South-East Pacific, Tumaco, Colombia, May, 1987	11
CPPS/UNEP/ECLAC Seminar on Radioactive Pollution in the South-East Pacific, Santiago, Chile, June, 1987	80
CPPS/UNEP/IOC/FAO/IAEA Regional Course on Analytical Techniques for the Identification of Heavy Metals and Pesticides in Marine Organisms and Sediments, Cartagena, Colombia, August, 1987	30
XVI Pacific Science Congress, Seoul, Korea, August, 1987	6
Regional Course on Analytical Techniques to Identify Petroleum Hydrocarbons in Marine Organisms and Sediments in the South-East Pacific, Valparaiso, Chile, September, 1987	30
CPPS/UNEP/ECLAC Workshop on the Sea Bed: Its Resources, Exploitation and Environmental Effects, Cartagena, Colombia, October, 1987	30
CPPS/UNEP/ECO(PAHO) Regional Course on Basic Techniques and Methods of Environmental Impact Assessment, Guayaquil, Ecuador, December, 1987	25

CONPACSE Phase II

The Extraordinary Intergovernmental Meeting held in Bogota, Colombia, in April, 1987, approved the formulation of CONPACSE II with the following main components:

--- Pollution monitoring in the South-East Pacific: a monitoring plan for the main areas on the basis of CONPACSE I results.

--- Environmental management: preparation of technical and legal guidelines to control pollution, including training and environmental planning.

--- Research on pollution: CONPACSE I studies still to be completed.

--- Implementation of the Lima Convention and its supplementary agreements as a result of its coming into force.

--- National proposals of regional interest.

Development of the legal component

Four legal instruments have been drafted, signed and ratified during the period 1981-1986. They are:

--- Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific. Entry into force: 19 May 1986.

--- Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or Other Harmful Substances in Cases of Emergency. Entry into force: 15 July 1986.

--- Supplementary protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or Other Harmful Substances. Entry into force: 20 May 1987.

--- Protocol for the Protection of the South-East Pacific against Pollution from Land-Based Sources. Entry into force: 23 September 1986.

The details of the signature and ratification of each of these legal agreements by each country are shown in Table 2.

The 1987 Extraordinary Intergovernmental Meeting in Bogota approved the preparation of two new protocols to the Lima Convention. These two new legal instruments are:

--- Protocol for the Protection of the National, Historical and Touristic Heritage, Recreation Areas and Areas of Scientific Interest in the South-East Pacific; and

--- Protocol for Environmental Impact Assessments in the South-East Pacific.

Table 2: Status of the ratification of the Lima Convention and its Supplementary Agreements (as of May 1987)

	Colombia	Chile	Ecuador	Panama	Peru
Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (Lima Convention)					
Signed:	12/11/81	12/11/81	12/11/81	12/11/81	12/11/81
Ratified:	26/02/85	26/12/85	11/10/83	06/05/86	
Deposited:	06/08/85	20/03/86	26/10/83	23/07/86	
Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or Other Harmful Substances in Cases of Emergency					
Signed:	12/11/81	12/11/81	12/11/81	12/11/81	12/11/81
Ratified:	26/02/85	14/05/86	11/09/83	05/05/86	
Deposited:	06/08/85	13/08/85	26/10/83	23/08/86	
Supplementary Protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or Other Harmful Substances					
Signed:	22/07/83	22/07/83	22/07/83	22/07/83	22/07/83
Ratified:	26/02/85			05/05/86	
Deposited:	06/08/85			23/07/86	
Protocol for the Protection of the South-East Pacific against Pollution from Land-Based Sources					
Signed:	22/07/83	22/07/83	22/07/83	22/07/83	22/07/83
Ratified:	26/02/85	26/12/85		05/05/86	
Deposited:	06/08/85	10/03/86		23/07/86	

Development of the Institutional Component

The First Intergovernmental Meeting in July, 1983, approved the establishment of a regional institutional network to carry out the activities foreseen in the CONPACSE Working Document. During 1984-85, CONPACSE was executed through 16 national institutions. For the period 1985-86, the number of national institutions and/or laboratories directly involved in CONPACSE increased to 26. By 1987, the CONPACSE network involved 42 institutions and laboratories:

Colombia
Institute of Renewable Natural Resources and Environment (INDERENA)
South-East Pollution Control Centre, General Port and Maritime Directorate (DIMAR)
Colombian Oceanographic Commission (COO)
General Port and Maritime Directorate

Chile
University of Concepcion, Oceanology Department
University of Valparaiso, Oceanology Institute and School of Chemistry and Pharmacy
University of Magellanes, Institute of Patagonia
Institute of Fisheries Development (IFOP)
Directorate of Maritime Territories and Merchant Marine

Ecuador
National Fishing Institute (INP)
Navy Oceanographic Institute (INOCAR)
University of Guayaquil, School of Chemical Sciences and School of Natural Sciences
Coast Polytechnic Higher School

Panama
National Environmental Commission (CONAMA)
University of Panama, Sea and Limnology Sciences Centre and Specialized Analysis Laboratory
Institute of Hydraulic Resources and Electrification

Marine Resources, Ministry of Commerce and Industry
General Directorate of Environment, Ministry of Health
National Aquaduct and Sewage Systems Institute

Peru
Peruvian Institute of the Sea
General Directorate of Physical Oceanography and Pollution
Directorate of Ecology and Physiology of Marine Organisms
General Directorate of Coast Guards and Harbourmasters, Maritime Ministry
Directorate of Hydrography and Navigation
Environmental Directorate, Ministry of Health
Federico Villarreal National University
Mayor de San Marcos National University
National Institute of Agroindustrial Development

International Co-operation

The United Nations Environment Programme (UNEP) has been associated with the South-East Pacific Action Plan from the early stages of its formulation, adoption, implementation and development; the support received from this Programme and its co-operation in each of the phases of the Action Plan has been decisive in meeting its objectives. UNEP's financial support and co-operation are in response to the request of the CPPS, acting in its capacity as Regional Co-ordinating Unit of the Action Plan, mandated by member Governments to implement all technical, legal and institutional affairs of the Plan. Some other international organizations have supported Action Plan activities, upon the request of CPPS or UNEP in accordance with the decisions taken jointly by these two organizations. These include:

--- International Maritime Organization (IMO)
--- International Atomic Energy Agency (IAEA)
--- Economic Commission for Latin America and the Caribbean (ECLA)
--- International Oceanographic Commission (IOC/Unesco)
--- United Nations Food and Agriculture Organization (FAO)
--- Swedish International Development Agency (SIDA)
--- Pan-American Health Organization (PAHO/WHO)

Development of the financial component

The Regional Trust Fund (FF/PSE) was established in 1981 to cover the operating expenses of the Action Plan. The First Intergovernmental Meeting held in Quito, Ecuador, in July, 1983, set US$525,000 as the allocation from member Governments for the period 1984-1986. Later, the Second Intergovernmental Meeting, held in the Galapagos Islands, Ecuador, in August, 1985, extended the funding period to July, 1987, so that it would coincide with the next Intergovernmental Meeting.

The Experts Meeting of December, 1986, recommended the extension of the Fund activities after January, 1988, and the April, 1987, Extraordinary Intergovernmental Meeting accordingly approved a new funding period of three years, 1988-1990, in the amount of US$525,000 to finance disbursements under CONPACSE II.

Contributions to the Trust Fund began in March, 1984, and 59% of the Government allocations were deposited that year, and again in 1985. By December, 1986, 54% of the allocations corresponding to that year had been deposited in the Trust Fund. Thus US$301,489, amounting to 56% of the pledged contributions, has been received by the Fund so far.

Contributions from the Environment Fund of UNEP to the Action Plan for the South-East Pacific for the period 1980-1987 amount to US$1,150,651. Counterpart contributions to the Action Plan by national Governments have been estimated at US$870,000, and the financial support provided by the CPPS has been estimated at US$560,000.

Recommendations for inter-regional co-operation

UNEP can play an important role in the co-ordination of inter-regional co-operative action. The following are some areas where inter-regional co-operation would be meaningful:

--- Development of short-term training programmes on specialized subjects, using the analysis of case studies of relevant technical applicability.

--- Organization of trans-Pacific seminars and workshops on subjects of interest to both sides of the Pacific basin, such as:
radioactive pollution
sea bed mining
marine freight.

--- Local development of appropriate environmental control technologies useful for adequate environmental management in the regions.

--- Exchange of information.

--- Determination of an appropriate forum for discussion of subjects of common interest, for making joint declarations, etc.

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TOWARD SOUND ENVIRONMENTAL MANAGEMENT OF THE PACIFIC COASTAL AND MARINE AREA OF COLOMBIA

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ABSTRACT

Little is known about the functioning, potentials and limitations of the marine ecosystems of the Pacific coastal area of Colombia, while the terrestrial ecosystems, considered the world's richest in terms of ecological diversity, are becoming scarce and dispersed. For these reasons, the National Institute for Natural Resources and the Environment (INDERENA) is implementing a policy addressed to the three main objectives proposed by IUCN in the World Conservation Strategy: conservation of genetic diversity, preservation of essential life support systems, and sustainable use of resources.

An increased environmental understanding of the region has led to the following steps: two new national parks have been created (Gorgona Island and Ensenada de Utria) and a possible third is being studied in Malaga Bay. A programme of marine pollution monitoring and control in Tumaco and Buenaventura Bays is underway as part of CONPACSE (South-East Pacific Action Plan). The initial results show the immediate need for pollution control in fisheries, wood processing and other industries. Another complex technical and operational activity is the implementation of the recommendations of the environmental impact studies of the new Bahia Malaga Navy Base. The project and the 107 km road connecting it with Buenaventura will lead to heavy immigration with important consequences for traditional tribes and fragile tropical forest ecosystems in the area.

Several measures are planned to guarantee the long-term environmental quality of the region, such as the creation of protected areas, and research on and development of appropriate and sustainable uses of the renewable natural resources, through a sound regional development scheme.

Introduction

The Pacific coast of Colombia has been one of the most marginal regions of the country for social and economic development, in spite of its immense forest, fisheries and mineral resources and its basic geopolitical interest to the nation. The development of its natural resources will provide the impulse for the integrated development of the coastal region, requiring the construction of infrastructure (roads, ports, energy, communications) leading to other productive activities for the benefit of the human population.

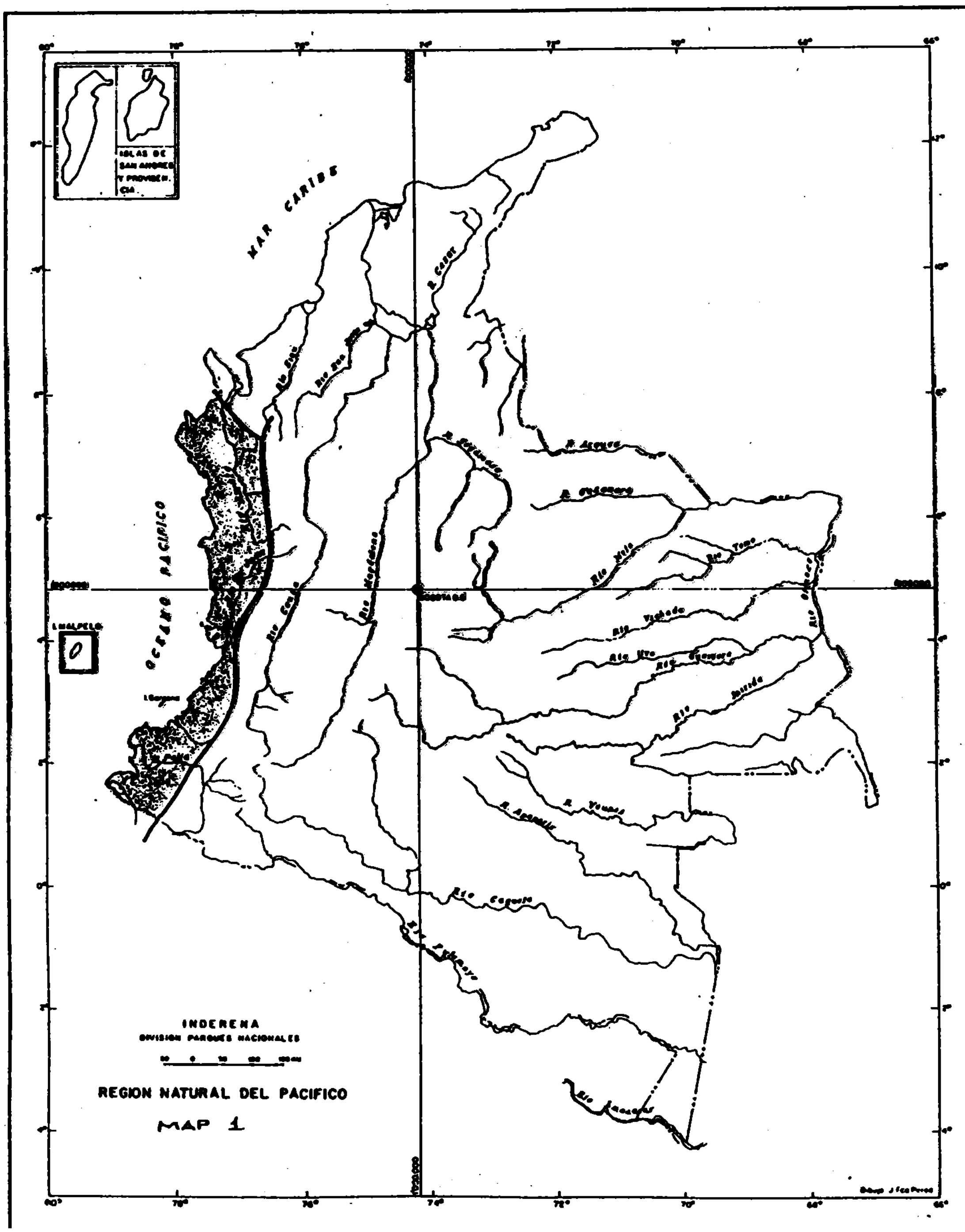
In order to anticipate the environmental effects of development projects, a study was begun in 1981 of the present state of the environment, particularly of Tumaco Bay and Buenaventura Bay, areas selected as the best actual and potential centres of industrial, commercial and urban activity on the Pacific coast of Colombia. The objective was to determine the existence, origins, and levels of pollutants in the ecosystems studied, including the analysis of water quality, the identification of pollution sources, and particularly the presence and amounts of toxic substances such as heavy metals. Water, industrial effluents and sewage were analyzed for their loads of organic matter, suspended solids and nutrients. Sediments and common organisms were analyzed for heavy metals.

On the basis of the results obtained in the first phase, the study was expanded to include microbiological analyses, measures of highly toxic elements like mercury, and an evaluation of the input of heavy metals from the major rivers as the most likely sources for these substances. The information obtained on water pollution levels has encouraged the application of measures to reduce the negative effects observed and identified a need for the government to adopt basic environmental standards.

The Pacific Coast of Colombia

The Pacific Coast of Colombia extends for 1,392 km from a point in Cocalito near Point Ardita (7°12'N, 73°53'W) to the mouth of the Mataje River (1°20'N, 78°45'W), representing the borders with Panama and Ecuador, respectively (Map 1).

Map 1: Pacific coastal region of Colombia



The coast north of Cape Corrientes is high and mountainous with occasional cliffs. To the south, the coast is low with sandy beaches, wide mangrove zones and extensive estuaries at the mouths of the numerous rivers, some of very large size such as the Mira, Patia and San Juan Rivers. The coastal platform covers 16,700 km^2. There are two oceanic islands, Malpelo and Gorgona, plus coastal islands such as Tumaco, Cascajal, El Mono, La Viciosa and Isla Palma and others, mostly in the river deltas.

The climate of the Colombian Pacific Coast can be classed as very humid tropical forest according to the Koeppen system. The predominant winds are from the south-west. The temperature is relatively stable throughout the year, ranging from 25° to 31°C, with a relative humidity, higher on the northern coast, reaching 85-96%.

Physico-chemical characteristics of the coastal waters

The ocean surface temperature varies between 24 and 30°C, sometimes increasing slightly to a depth of 10-12 m before decreasing slowly with depth, reaching 3°C at 1,500 m. The surface temperature is a little higher to the south of Cape Corrientes than to the north, with values averaging 26-28°C. The temperature varies depending on the oceanographic conditions at different times of the year.

In general, the lowest salinities are found in the coastal areas influenced by river discharges. The salinity approximates 32 $^{o}/_{oo}$ to the north of Cape Corrientes, while it is lower to the south because of the large input of fresh water. Surface oxygen values average 4.5 mg/l in the north and 2.5 mg/l in the south. Nutrient levels give concentrations of phosphates and nitrates of 1.5 mg-at/l and 0.5 mg-at/l respectively, and tend to be higher in the north than in the south.

The general ocean circulation follows a counterclockwise pattern, while the coastal currents are primarily the result of the ebb and flow of the tides. The tides are predominantly semidiurnal, with two highs and two lows of similar amplitude every 24 hours. The tidal amplitude increases near the coast, and is highest in the bays and coves. The tidal range varies between 4 and 5 m.

Terrestrial biological resources

The Pacific littoral zone of Colombia is covered for almost its entire length by tropical rain forest which is typified by impressive trees with a highly diverse fauna and flora. A considerable number of genera of both plants and animals are shared with Amazonia, suggesting distributions that may date from before the final lifting of the Andes. The terrestrial fauna is abundant, with a total of over 500 species of reptiles, mammals and especially birds.

The forest resources are significant. The mangrove forests total over 280,000 ha of which much is regenerating after former overharvesting to extract the bark. The low hill forest, of which there is something less than 2-3 million hectares, contains more than a hundred species that can be used to make paper pulp, with a potential yield of 150 m^3/ha. The transitional swamp forest between the mangroves and dry land has already been almost entirely exploited for its valuable tree species.

Marine biological resources

Although no extensive biological studies exist for the Pacific coastal waters of Colombia, the southern part is the best known and has the greatest fisheries potential. The zone of highest productivity is near the coast over the continental shelf, especially south of Cape Corrientes. A stationary upwelling has been observed off this cape.

The extensive mangrove and estuarine areas along the south coast, combined with favourable salinity, oxygen, temperature, turbidity, tides and substrates, give the ecosystems a high potential for the production of large quantities of marine species. Evaluations of the coastal fisheries potential have estimated the stock available for capture by industrial and artisanal methods at 156,500 tons/year for fish, crustaceans and molluscs of commercial importance.

Water quality

The principal population and development centres along the coast are the ports of Buenaventura and Tumaco, whose waste waters and refuse drain into their respective bays and coves. The other sites are very small and contribute no significant pollution, except for some wood processing plants.

The major pollution sources that have been identified are the wood and fish processing industries, the wastes from port operations, dry docks and vessels, accidents involving the oil pipeline and underwater fuel transfer facilities, and thermal pollution. The major sources, quantities and characteristics of the effluents are given in Table 1.

Table 1: Pollution sources along the Pacific Coast of Colombia

	Buenaventura		Tumaco	
	1981-83	1985	1981-83	1985
Wood industries				
Number	4	13	7	---
Water consumption (m^3/yr)	130,000	22,021	89,146	---
Liquid industrial effluents (m^3/yr)	111,435	20,710	35,200	---
BOD_5 (tons/yr)	437	---	3,000	---
Liquid domestic effluents (m^3/yr)	5,752	11,345	1,850	---
BOD_5 (tons/yr)	2.1	---	11.8	---
Fishing industries				
Number	10	14	10	8
Water consumption (m^3/yr)	380,042	345,840	217,165	63,164
Liquid industrial effluents (m^3/yr)	250,000	243,184	151,900	48,931
BOD_5 (tons/yr)	15.7	---	25.54	---
Solid wastes (tons/yr)	506	2,036	1,337	124
Liquid domestic effluents (m^3/yr)	6,609	16,908	3,432	3,536
BOD_5 (tons/yr)	8.57	---	8.86	---
Other industries				
Number	2	10	2	---
Water consumption (m^3/yr)	73,000	106,411	41,150	---
Liquid industrial effluents (m^3/yr)	250	61,539	420	---
Solid wastes (tons/yr)	variable	variable	variable	---
Liquid domestic effluents (m^3/yr)	1,808	4,496	600	---
Chemical industry				
Number	1	---	0	---
Liquid industrial effluents (m^3/yr)	1,530	---		---
BOD_5 (tons/yr)	1.09	---		---
Liquid domestic effluents (m^3/yr)	1,703	---		---
BOD_5 (tons/yr)	0.45	---		---
TOTAL				
Number of industries	16	27	19	---
Total effluent volume (m^3/yr)	361,685	325,433	187,520	---
Domestic effluent volume (m^3/yr)	14,169	32,839	5,882	---

Table 2: Pollution loads in Pacific Ocean from municipal discharges
(Calculated using WHO coefficients and 1973 census data)

Region		No. of Municip.	Population Connected	Population Not Connect.	Municipal Effluents m3/yr	Pollution load (tons/yr) BOD	COD	SS	TDS	N
1	urban	1	46,063	105,961	4,136,114	1,638.57	3,722.14	2,616.63	1,681.29	152.00
	rural		24,069	175,704	166.07	385.10	385.10			
2	urban	5	222	61,673	466,419	429.91	976.53	991.19	8.09	0.73
	rural		63,720	465,156	439.66	1,019.50	1,019.50			
3	urban	6	159	71,618	534,418	497.29	1,152.88	1,149.07	5.80	0.52
	rural		35,511	259,230	245.02	568.17	568.17			

While the pollution situation on the Pacific Coast of Colombia cannot be considered serious, it is preoccupying, particularly for pollution by pathogenic microorganisms and metals (especially mercury) with the effects that these can have on human health.

To correct these effects, the governmental entities that are responsible for the application of legal measures must show courageous leadership in taking joint action to reduce the pollution in urban coastal areas and in the river basins emptying into the Pacific where industrial or artisanal mining is taking place. The costs of mitigating the present pollution can be significantly reduced by undertaking educational campaigns at all levels to explain to the inhabitants of the region the origins, the causes and the consequences of pollution, as well as alternatives for the management and rational exploitation of the natural resources present in the area. To achieve these objectives, Colombia will need to draw on international experience in the modern methods and technologies necessary to correct present problems.

Plan for the integral development of the Pacific Coast (PLADEICOP)

As indicated above, the Pacific Coast is one of the least socioeconomically developed and physically integrated areas of Colombia, despite having immense actual and potential natural resources (living and mineral) in both its terrestrial and marine areas. For this reason, in November 1984 the National Council for Economic and Social Policy (CONPES) approved the "Plan for the integral development of the Pacific Coast" (PLADEICOP), with short, medium and long-term objectives and the corresponding strategies and policies to achieve them. The plan includes general environmental considerations and guidelines, but specific action programmes and projects remain to be designed and implemented.

The PLADEICOP general objectives include the following:

1. To increase the standard of living in the region through employment and production opportunities, and attention to basic needs and physical infrastructure.

2. To integrate the Pacific region with the rest of the nation physically, socially and economically.

3. To guarantee the optimum and rational use of the natural and human resources of the region, protecting and respecting the existing ethnic, cultural and natural values.

4. To strengthen the process of community participation.

5. To develop high inter-institutional co-ordination to assure the continuity and efficiency of the programme in the long term.

The plan proposes ambitious long-term projects such as the construction of the interoceanic channel (Atrato Channel), the mining of submarine polymetallic nodules, the master plan for living marine resources, a grant for an alumina processing factory, the Naval Base in the Bahia Malaga (already under construction), and an important hydroelectric generation programme (San Juan, Patia I and II, and Micay for an estimated 5,540 MW). It also includes the short- and medium-term sectorial strategies described below.

Physical infrastructure

Roads and transportation:
- construction of several rural roads;
- construction of inland waterways between Tumaco, Buenaventura and Jurado-Curiche;
- studies for a major new port in Bahia Solano and for port improvements in Tumaco and Buenaventura;
- studies and construction of 18 small and middle-sized ports to develop a regional coastal traffic network supporting increased trade.

Energy sector:
- regional energy supply and demand studies to implement the best combination of energy options;

- design of several hydroelectric projects of different sizes, including 20 micro units of up to 150 kw each, a 2,400 kw unit in Bahia Solano (Choco), an isolated energy system in the geographic triangle Toli-Alto Canal-Santa Catalina, and a transmission line from Pasto to Tumaco.

Communications sector:

- design and development of telephone, telex, radio, television and mail networks as well as aerial navigation aid systems.

Production sector

Forestry:

- detailed assessment and inventory of the forest potential for extraction and silviculture;
- implementation of management plans for the main forest formations (guandal, natal and manglar) including support for research on agroforestry technologies appropriate for the area and for specific species such as Gum Arabic (Hevea spp.);
- development of a technical wood collection and trading system including main centres in Buenaventura and other locations;
- modernization of the existing wood cutting, extracting and transforming processes and promotiion of community production associations;
- provision of an efficient system of technical assistance to the micro and small wood-related businesses.

Fisheries:

- tuna fish potential studies (other species);
- design and construction of a major fisheries port in Buenaventura;
- organization of small and middle sized fishermen's co-operatives along the coastal and inland river areas;
- promotion of shrimp aquaculture;
- support for research on marine and coastal resources.

Mining:

- detailed assessment and inventory of the mining potential of the region;
- exploration and development of mining sites considered of high potential;
- technical assistance for small mining ventures along the rivers;
- implementation of adequate environmental measures for these activities.

Agriculture and cattle:

- specific studies to increase food production through the use of promising animal and plant species and the control of different pests;
- reinforcement and widening of present research, promotion and technology transfer on agriculture and cattle, aiming for increased production in activities such as "chontaduro", rice, sugar cane, fruit trees, coconut oil, cocoa, palmitos and pigs.
- definition of the legal and physical boundaries of the indian reservations and the new settlements.

Tourism:

- assessment of the tourism potential of the Pacific Coastal area;
- strengthening the tourism sector economically and technically, providing adequate infrastructure for its development.

Social sector strategies

Education:

- design of an appropriate educational curriculum for the region, taking into account its ecological and cultural values and characteristics;
- guarantee an early and continuing participation of children in the formal and informal educational systems, such as with the "Escuela Nueva" (New School) method;
- increase in the quality of all levels of the educational system, including university level;
- implementation of an educational model that prepares social promoters in different areas;
- increase in adult education and access to regional cultural opportunities.

Health:

- water supply and quality, waste disposal and morbidity/mortality studies that permit detailed sanitary diagnostics;
- establishment of a regional centre for environmental (sanitation) technology and a regional network for its application;
- implementation and/or increase in the level of regional health services;

- construction of the necessary sanitation infrastructure.

Housing:

- use of appropriate housing technologies to solve existing dwelling needs, including self-building and co-operative endeavors;
- improvement of living conditions through programmes for upgrading existing housing;

Many aspects of the plan involve the indian communities, since nearly 30,000 indians live in the area. The plan should involve about 43 communities in 23 municipalities.

Legal and institutional framework

Environmental and renewable natural resources legislation has existed in Colombia for several years. The relevant laws and decrees include a "National Code for the Environment and Renewable Natural Resources", health legislation, marine legislation, and various decrees on nature conservation, resource management and pollution control. These legal instruments provide the operational base for the adequate management of terrestrial and marine renewable natural resources, although many are so recent that they are still in the process of being enforced, and some may need to be further elaborated.

There are several governmental and private institutions involved in the Pacific region at the national, regional or local level. Renewable natural resources and environmental issues are covered by the Ministries of Health, Agriculture and Defence through regional offices or subsidiary bodies. The Ministry of Health has its own offices in Buenaventura and Tumaco under the regional responsibility of the state (Departamento) Governor. The Ministries of Agriculture and Defence are represented through INDERENA and DIMAR, respectively. INDERENA, the National Institute for Renewable Natural Resources and the Environment, is in charge of the biotic resources in both terrestrial and aquatic environments, while DIMAR, the Direction for Marine Issues, is responsible for possible marine pollution events and for coastal protection. In addition, a regional development corporation, the CVC (Corporacion del Valle del Cauca), has been assigned to co-ordinate the regional development plan for the Pacific area (PLADEICOP). While its geographic responsibilities do not include the coastal zone, it does cover sectorial tasks such as improvement of infrastructure for health, education and basic primary services (potable water, sewerage, electricity, etc.), and promotion of the use of fisheries and forestry resources for regional development.

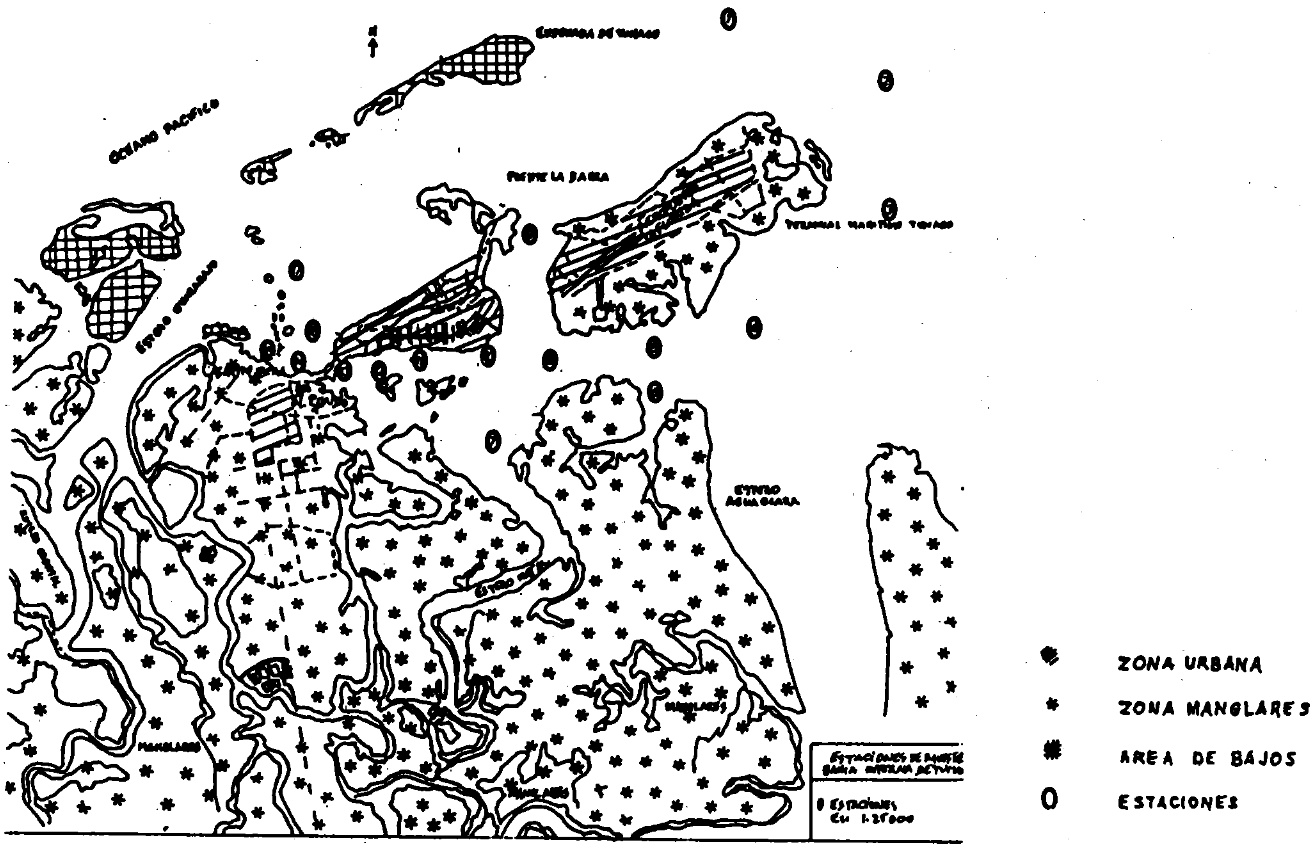
Pollution control and monitoring

A monitoring and control programme for water pollution has been implemented with increasing effectiveness since 1981. The programme aims to identify, measure and control pollution from agricultural, domestic, industrial and mining activities, with special emphasis on environmentally sensitive geographic areas.

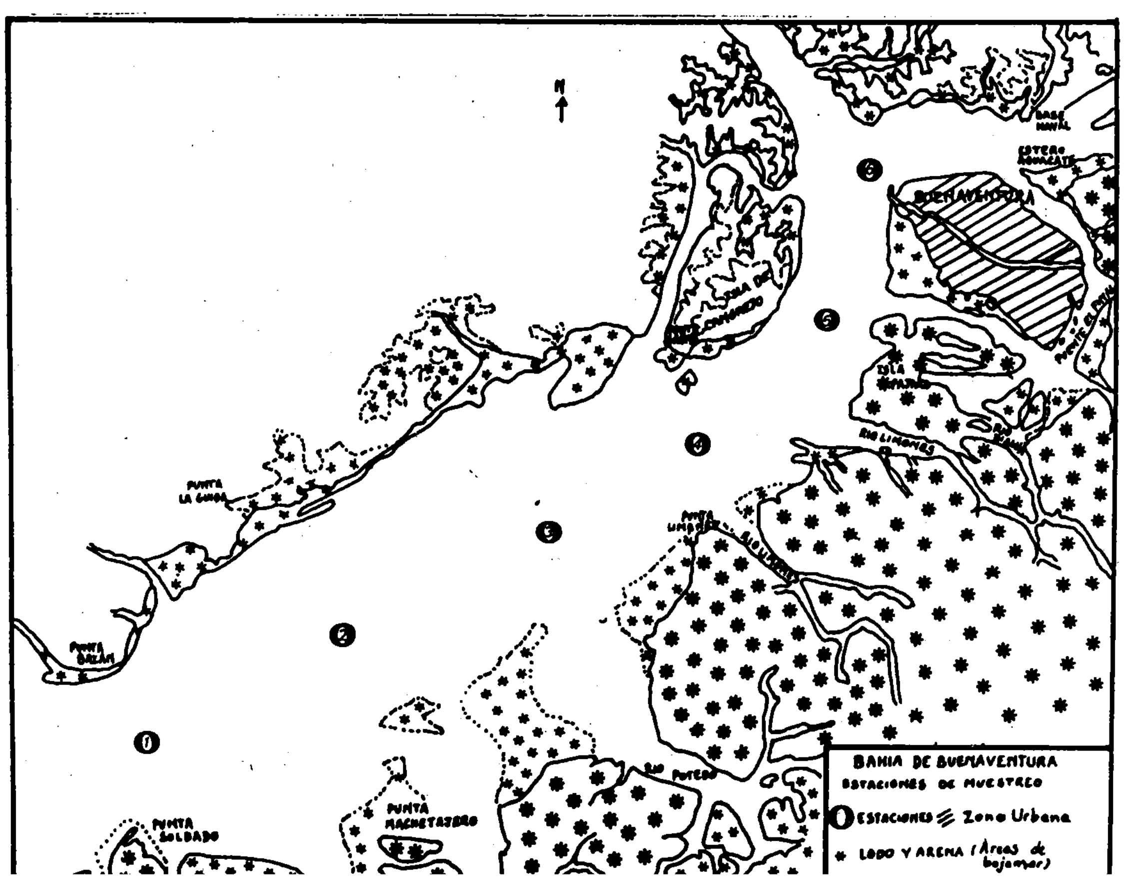
The most recent studies monitoring water pollution in the Pacific region have been conducted by INDERENA and DIMAR, partly in compliance with CONPACSE activities, and mainly involving Tumaco and Buenaventura Bays. Fernandez and Pion, with the collaboration of Pulido and Baena, have sampled several times in both places since 1985 and have produced two preliminary reports (Fernandez and Pion, 1986, 1987). The first report (1986) estimates the individual contributions of industrial and domestic sewage to the coastal waters. Monitoring has continued during 1986 and 1987 with modified sampling locations and the addition of microbiological quality parameters and toxic elements such as mercury and other heavy metals. The sampling locations are shown in Maps 2 and 3. Water samples were taken at three different depths, with tidal behavior taken into account. Sediments and organisms were also collected for analysis.

Methods used included those of Strickland and Parsons (1972) for nutrients and chlorophyll, and of APHA (1980) for suspended solids and BOD. Heavy metals in sediments were analysed by atomic absorption spectrophotometry. Five species of bivalves were used as bioindicators, *Anadara similis*, *A. tuberculosa*, *A. grandis*, *Donax panamensis*, and *Andostrea coticienzis* using the methods of UNEP/CPPS (1984).

Map 2: Tumaco area showing sampling stations



Map 3: Buenaventura Bay showing sampling stations

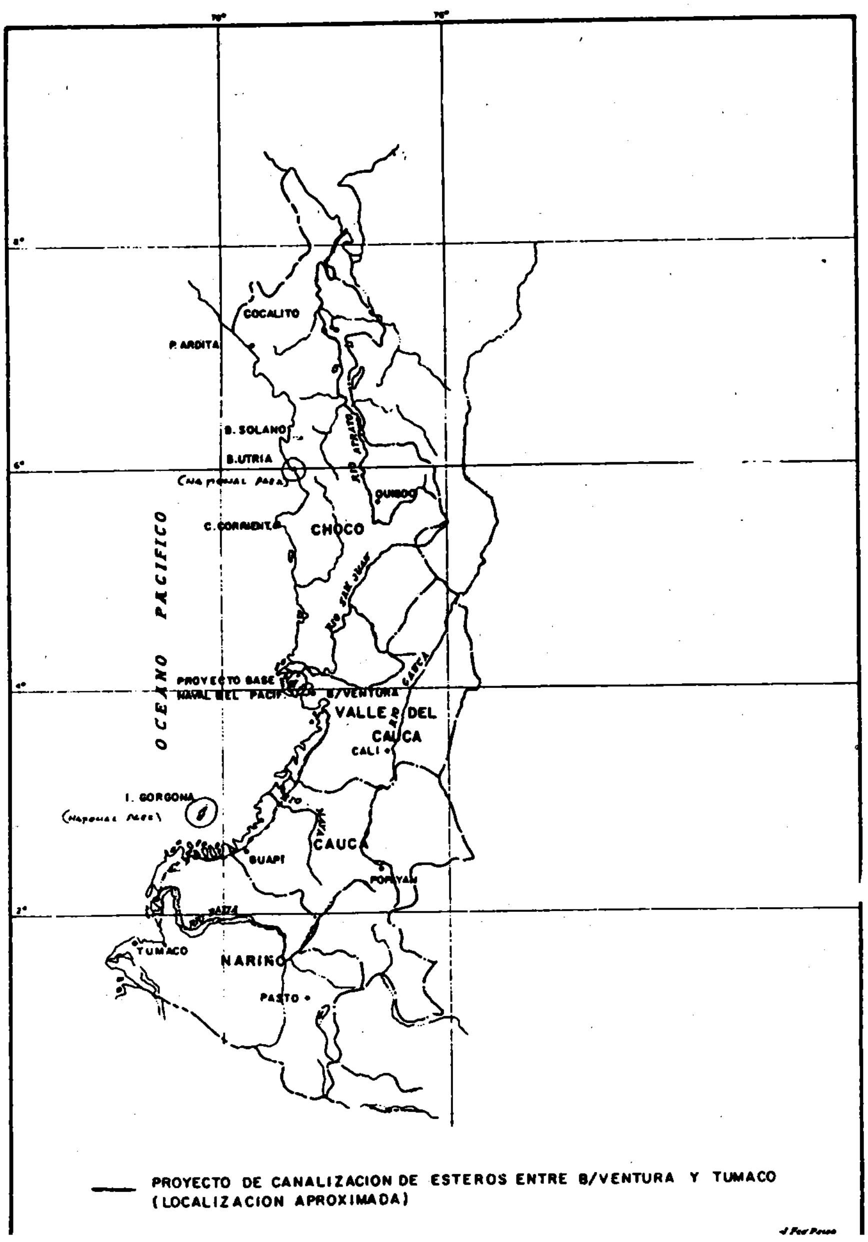


Emphasis has been placed on the environmental assessment of development projects in order to minimize their possible impacts and ensure their integration into the local natural and cultural environment. Some examples are the naval base at Bahia Malaga, the Tumaco-Buenaventura inland waterway, and the 2400 KW Mutata microhydroelectric plant near Bahia Solano.

The environmental studies of the ecological and socioeconomic impact of the naval base at Bahia Malaga (Malaga Bay) show that the base and the associated 107 km road connecting it with the existing Cali-Buenaventura road will induce a direct or indirect population increase of 20,000 over the existing 2,000 in the area. The road traverses humid rain forest of very high biotic diversity that will certainly be affected by settlers attracted to the area. The existing tourist sites of Juanchaco and Ladrilleros will experience heavy immigration. It will be necessary to implement appropriate technologies for the use of terrestrial resources, adequate land use planning and basic infrastructure for incoming people. In addition, basic research is needed to identify and understand the richness of the biota in the zone and to design a protected area of adequate size.

The Tumaco-Buenaventura inland waterway will involve the dredging and connection of existing swamps, mangrove areas and rivers (Map 4) to provide a faster means of inland transportation since the Pacific Ocean is so rough. A detailed assessment of the effects of piling the dredged material on the mangrove areas has led to the identification of special disposal places with low impact on mangroves.

Map 4: Location of the projected Tumaco-Buenaventura inland waterway and National Parks



The 2400 KW microhydroelectric plant involves a power house, a little reservoir and 800 m of tunnel, plus transmission lines and an access road, which are mainly located within the boundaries of the new National Park of Bahia Utria. This has challenged the environmental design capability of INDERENA, requiring the analysis of alternatives for the location, the characteristics of the energy source, and the route of the road. The local need for energy is high, so the work must be conducted under time pressure.

Environmental land use planning

On the basis of the scientific surveys, two new National Parks were created in 1985, one at Bahia Utria, and the other on Gorgona Island, a 24 square km island 60 km from the coast. A possible third park is being studied in Malaga Bay.

Pollution in Tumaco Bay

The Tumaco area (Map 2) receives the outflow from the Yanaje, Cucuy, Colorado, Chaqui, Tablones, Mejicano and Rosario Rivers, and is indirectly but greatly influenced by the Mira River to the south and the Patia River to the north. The river flow and current patterns in the bay are greatly influenced by the tides. River monitoring for heavy metals is critical, because the Pacific region is rich in precious metals, especially gold. Exploitation techniques are still primitive, and mercury is used to extract the gold, resulting in high levels of it in the water. Monitoring the Mira and Telembi Rivers is the most important, as the Mira is the potable water source for Tumaco, and the Telembi is where most gold mining activity is concentrated. The water sampling and analysis results for Tumaco are as follows (INDERENA, 1986):

INNER BAY:

Salinity: surface salinity remained between 15-29 $^{o}/_{oo}$ while bottom salinity was 17.5-29 $^{o}/_{oo}$, always higher in the bottom suspended solids.

Light penetration: low at all times.

Dissolved oxygen: at low tide, values were 4.67-7.22 mg/l (surface) and 4.62-7.41 mg/l (bottom); at high tide, 3.40-6.669 mg/l (surface) and 3.81-6.46 mg/l (bottom). The lowest values were found near the wood mills.

BOD: generally low, with the highest values, 3.4-3.8 mg/l, in the bottom samples near the wood mills.

Nutrients: nitrogen and phosphorus concentrations were generally low, with the principal sources of ammonia and nitrates being the rivers and domestic sewage. Dissolved silicates were inversely related to salinity values due to the higher levels in the rivers.

Bacteriology: faecal coliforms were found in much higher quantity than permitted by Colombian norms (Decree 1594/84) for several sampling stations in the inner bay.

Bottom sediments: cadmium, copper, mercury, lead and zinc were detected in bottom sediments as shown in Table 3. The highest concentrations of cadmium, copper, lead and zinc were recorded near the El Pindo bridge in the area most influenced by the rivers, mainly the El Mira River.

Table 3: Heavy metal concentrations in bottom sediments in Tumaco (mg/kg dry weight)

	June 1986	October 1986
Copper	47.4 - 64.2	13.5 - 75.78
Zinc	13.17 - 132.8	48.42 - 92.7
Cadmium	0.39 - 1.06	0.33 - 1.07
Lead	5.78 - 18.79	5.10 - 22.02
Mercury	0.23 - 0.75	0.14 - 0.5

RIVERS:

Nutrients: the Mira and Curay Rivers showed normal concentrations: silicates 3.800-5.000 mg/l; nitrates 0.096-0.143 mg N/l; ammonia 0.014-0.085 mg N/l; orthophosphate 0.014-0.024 mg P/l; nitrite insignificant.

Suspended solids: high in the Mira River (193.2-391.5 mg/l) of which 90% was inorganic; 35.0 mg/l in the Curay River with 4.2% organic matter.

Heavy metals: amounts in the water column are shown in Table 4. Average metal concentrations in the bottom sediments near the mouth of the Yanaje, Curay, Colorado, Chaqui, Tablones, Mejicano and Rosario Rivers were: cadmium 0.56 mg/kg; copper 28.46 mg/kg; lead 16.65 mg/kg; zinc 81.85 mg/kg; and mercury 0.32 mg/kg. These values are higher than those in the inner bay except near the El Pindo bridge.

Table 4: Heavy metals in river water (mg/l)

Metal	Standard		River	
		Mira	Telembi	Curay
Cadmium	0.01	---	0.004	---
Copper	1.0	---	0.022-0.031	0
Lead		0	0	0
Mercury	2.0	9.17-9.79	3.70-5.40	10.5
Zinc	15.0	0.003-0.118	0.050-0.094	0.025

BIVALVES: the results of heavy metal analyses of bivalves are given in Table 5. Cadmium levels were well over maximum permitted levels of 0.05 mg/kg in Chile and 0.1 mg/kg in Venezuela except in Donax. Relatively high amounts of copper are present because it is incorporated in hemocyanine, a molluscan respiratory pigment. Copper levels exceeded the 10 mg/kg maximum permitted level in Venezuela in 29% of the samples studied. No lead was detected, and mercury was less than 0.5 mg/kg. Zinc contents were relatively high, but only Ostrea exceeds the 100 mg/kg wet weight Chilean standard.

Table 5: Heavy metals in bivalves (mg/kg fresh weight)

Metal	Maximum permitted	Anadara tuberculosa	Anadara similis	Ostrea	Donax panamensis
Cadmium	0.05-0.1	0.65-1.13	0.8-1.40	0.69	none
Copper	10	1.11-14.11	2.95-13.67	245	1.63-12.77
Lead		none	none	none	none
Mercury		<0.5	<0.5	<0.5	<0.5
Zinc	100	2.7-18.86	1.05-82.2	260.4	16.98-52.38

On the basis of the above results, it is recommended that sampling and monitoring in Tumaco Bay be continued, with special attention to fecal coliforms because of the health risks for the local population. Monitoring of fungi, Salmonella and other microorganisms is starting in 1987. Pollution from wood-related activities must be controlled. Mercury must be checked in the rivers that are the water supply for the Tumaco urban area (population 40,600 in 1984).

Since Tumaco is a petroleum port, the Navy has made oil and hydrocarbon analyses there as part of the CONPACSE programme.

Pollution in Buenaventura Bay

Buenaventura Bay (Map 3) is an estuary fed by the Dagua, Anchicaya, Potedo and El Raposo Rivers. The city of Buenaventura, with 173,600 inhabitants, is the biggest port in Colombia (60% of the traffic load) and contains wood mills, fisheries and fuel storage facilities. The region is rich in minerals, mainly gold.

Salinity depends on the volume of fresh water entering the bay, giving surface salinities at low tide of 12.5-24.5 $^{o}/_{oo}$ and at high tide of 14.0-22.0 $^{o}/_{oo}$. Salinity increases with depth, resulting in bottom low tide levels of 20.0-31.0 $^{o}/_{oo}$ and high tide levels of 15.0-23.0 $^{o}/_{oo}$.

Temperature appears to be unstratified.

Suspended solids produce water with low transparency and high solids concentration of which 99% are inorganic in origin. Their spatial distribution is inversely related to salinity and directly related to the characteristics of incoming river water.

Dissolved oxygen levels are obviously related to depth, with surface concentrations of 6.0 to 7.54 mg/l at high tide and 3.8 - 9.86 mg/l at low tide. In 2 out of the 16 sampling stations, dissolved oxygen is lower than the 4.0 mg/l required to maintain aquatic life (Decree 1594/84).

BOD values ranged from 10 to 3.8 mg/l, with the highest amounts being closest to a city waste water discharge. Tidal currents seemed important in flushing the wastes.

Nutrients: nitrates are present in the bay in relatively high concentrations, 0.027 - 0.539 mg/l in December and 0.009 - 0.094 mg/l in March. The Dagua River has an ammonia level of 0.239 mg/l. Orthophosphates originate in industrial and domestic effluents and in the incoming rivers. December, the wettest month of the year, shows 0.155 mg/l at Dagua River. Silicates occur in high concentrations near the river mouths.

Bacteriology: the low salinity levels in Buenaventura Bay favour higher faecal coliform counts, which exceeded acceptable levels at practically every sampling station. The faecal coliform/faecal streptococcus ratio was higher than 2, proving the human origin of the pollution.

Bottom sediments: the mercury level in bottom sediments varied between 1.89 and 6.57 mg/kg in December 1986, partly as a result of the recent mechanical removal of bottom sediments by a chinese ship.

Conclusions

There is an increasing interest in environmental matters at different government levels. First, an Environmental Policy Division was recently created in the National Planning Department, with responsibility for defining the environmental and natural resource policies for each of the six main regions of the country with the strong support of INDERENA.

Second, INDERENA is implementing several conceptual and operational activities to ensure that environmental matters are taken into account in an adequate and timely way in every project or programme that is conceived for the region. For this reason, a Regional Environmental Unit is being created based in Buenaventura, to work in close interaction with other institutions such as DIMAR. It will have sufficient laboratory facilities and personnel to monitor and control efficiently the different pertinent parameters.

In addition, in compliance with Decree 2811/74, every project is being requested to present a declaration of Environmental Effects and, if necessary, an Environmental Impact Study, in accordance with an environmental sequence for projects prepared by INDERENA for a proposed Decree on Environmental Requirements (Studies and Management Plans) for Projects.

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SOURCES OF POLLUTION AND PRINCIPAL POLLUTED AREAS IN THE PACIFIC COASTAL WATERS OF ECUADOR

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ABSTRACT

Pollution in the Pacific coastal waters of Ecuador is mainly confined to small areas such as the Estero Salado, Guayas River, lower reaches of the Daule River, Esmeraldas River and Teaone River. The nutrient content of the Estero Salado is influenced by the city of Guayaquil and by the shrimp-farming industry. The high concentration of nutrients in the Guayas River is associated with the direct discharge of sewage. The nutrient levels in the Daule River show the input of water from the Guayas River, and also the effects of industrial effluents in the neighborhood. Nutrient levels in the Esmeraldas River may be the result of domestic discharges from the city of Esmeraldas and of refinery effluents. The Teaone River also has raised nutrient levels from refinery effluents.

The amount of copper in the Guayas and Daule Rivers exceeds the maximum tolerance for living aquatic organisms. The presence of cadmium is associated with industrial effluents from the city.

Pollution by petroleum hydrocarbons is generally absent in the areas studied except where there is carelessness in oil handling operations.

Introduction

Very little work on pollution has been carried out in the coastal waters of Ecuador. The few studies made show that pollution levels are increasing, principally in the waters adjacent to Guayaquil, the most populated city in the country. The increased use of detergents, metals in industry, pesticides in agriculture, and petroleum hydrocarbons in transport and other uses over the last 20 years has raised the levels of pollutants in the rivers and related estuarine environments.

As part of the world-wide concern for pollution, the Instituto Nacional de Pesca (National Fisheries Institute) started a co-operative programme with the Permanent Commission for the South Pacific (CPPS) to identify the areas of significant pollution in Ecuadorian waters. This study identified the sources of pollution and the principal areas impacted. A brief description of these studies is given below.

Sources of pollutants

The pollution along some sections of the Ecuadorian coast has come from the following sources:

1. **Domestic and industrial discharges from the city of Guayaquil, including solid wastes.**

Guayaquil, the largest city in Ecuador with a population of 1,381,620 (Departamento de Planeacion urbana, 1986) and extensive industrial development, produces the largest pollution load in the coastal waters of Ecuador. The city is growing at a rate of 4.5% at present, including 1.6% internal growth and 2.9% from migration. By 1990, the population of Guayaquil will be 1,750,000, and it should reach 2,700,000 by the year 2000. Sanitation services covered 62.15% of the population in 1982, leaving 745,000 people without sanitation. Marginal and industrial developments occupy a considerable area of the city and its sanitation service. The most populated section of the city, parroquia Febres Cordero, with approximately 300,000 inhabitants (Figure 1), discharges its wastes without pretreatment into the Guayas River and Estero Salado. The volume and biochemical oxygen demand (BOD) of the daily sewage discharge are given in Table 1 (Empresa Municipal de Alcantarillado de Guayaquil, EMAG, 1979). There are 856 industries within the city and its surrounding area (EMAG, 1980) consuming 788,021 cubic metres of drinking water per month. The industries located in the urban section of the city discharge their effluents directly or indirectly into the Daule River (Figure 2). Table 2 shows the important characteristics of the 26 most representative industries in the city of Guayaquil. These industries discharge a volume of 253 cubic metres per day with a total daily organic load (BOD_5/day) of 4,106.5 (EMAG, cited in DPAMG, 1986).

Figure 1: Distribution of the population of Guayaquil 1909-1985

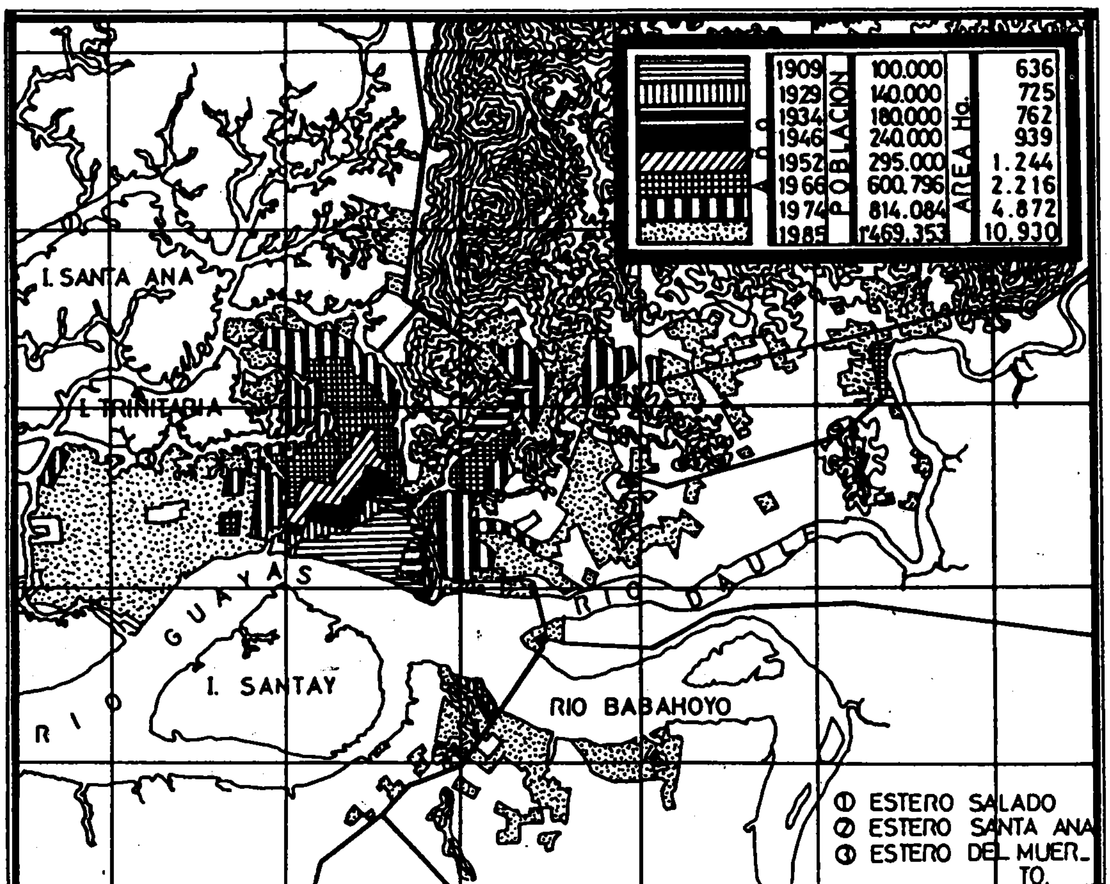


Table 1: Characteristics of the Guayaquil sewage discharge
(from EMAG, quoted by DPAMG, 1986)

System	Average BOD_5 (mg/l)	Daily discharge (m^3/day)	Organic load (kg BOD_5/day)
North	93	69,950	6,505
South	121	72,325	8,751

Figure 2: Industrial districts of Guayaquil

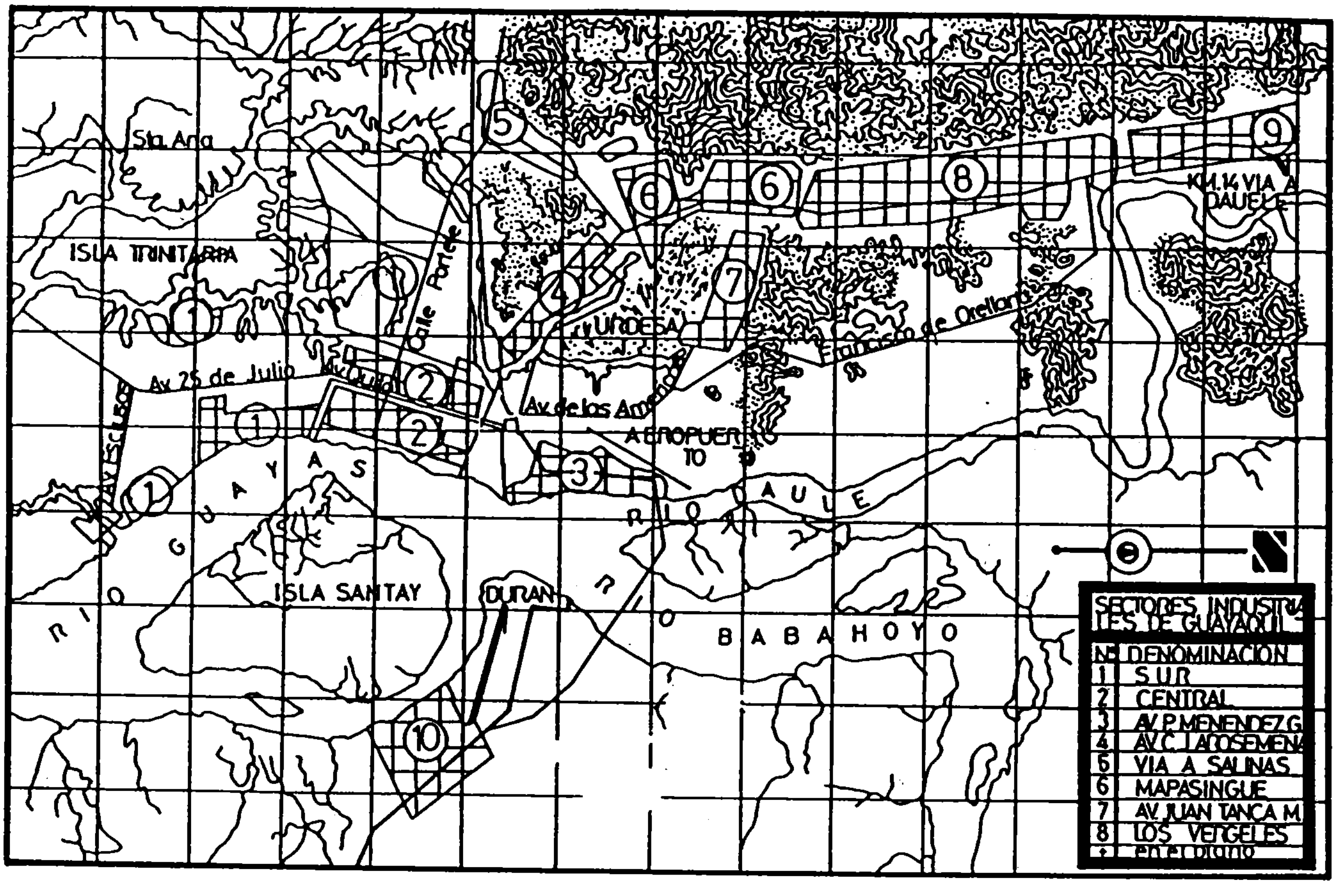


Table 2: Representative industries in the city of Guayaquil (from EMAG, quoted in DPAMG, 1986)

Industry	Waste volume (m^3/day)	Organic load production (kg BOD_5/ton)	Organic load (kg BOD_5/day)	Receiving waters
Tannery	20.0	0.70/bandas	140.0	Daule River
INASA	23.0	138	18	Daule River
Brewery (Pascuales)	555.2	0.08	236	Daule River
Tiles and Mosaics	518.4	0.000	0	Daule River
CEGALSA	60.0	0.000	0	Daule River
Primatex	25.2	-	6.5	Daule River
Paints	10.8	-	1.2	Daule River
Dairy products	30.2	2.94	105.08	Daule River
IJESA	172.8	3.84	103.7	Daule River
Alcohols	300.0	66.18	900.0	Guayas River
Shrimp packing	770.1	44.26	386.8	Guayas River
Brewery (Las Penas)	1382.4	0.32	760.0	Guayas River
Soap making	1200.0	8.33	600.0	Guayas River
Johnson & Johnson	21.6	-	0.9	Guayas River
Marines	0.7	0.25	0.4	Guayas River
SI Coffee	60.5	27.65	193.0	Estero Salado
Chemicals	69.1	-	76.6	Estero Salado
Nail manufacture	0.6	0	0	Estero Salado
Beterias	15.6	0	0	Estero Salado
Cannery	26.6	2.41	8.6	Estero Salado
Oils	650	69.52	520.0	Estero Salado
AGA Acetylene	30.0	0	0	Estero Salado
Gases	108.0	5.4	129.6	Estero Salado
Textiles	178.0	-	87.1	Estero Salado
Transcafe	267.8	22.5	225.0	Estero Salado
Expelca	22.8	0.12	1.6	Estero Salado

Solid wastes are becoming one of the biggest problems in Guayaquil because of a shortage of trucks, workmen and containers. According to Silva (quoted in DPAMG, 1986), the city will produce 1,573 tons of solid waste per day by 1990. Automotive wastes are put freely into the sewers and drains uncontrolled by any governmental organization.

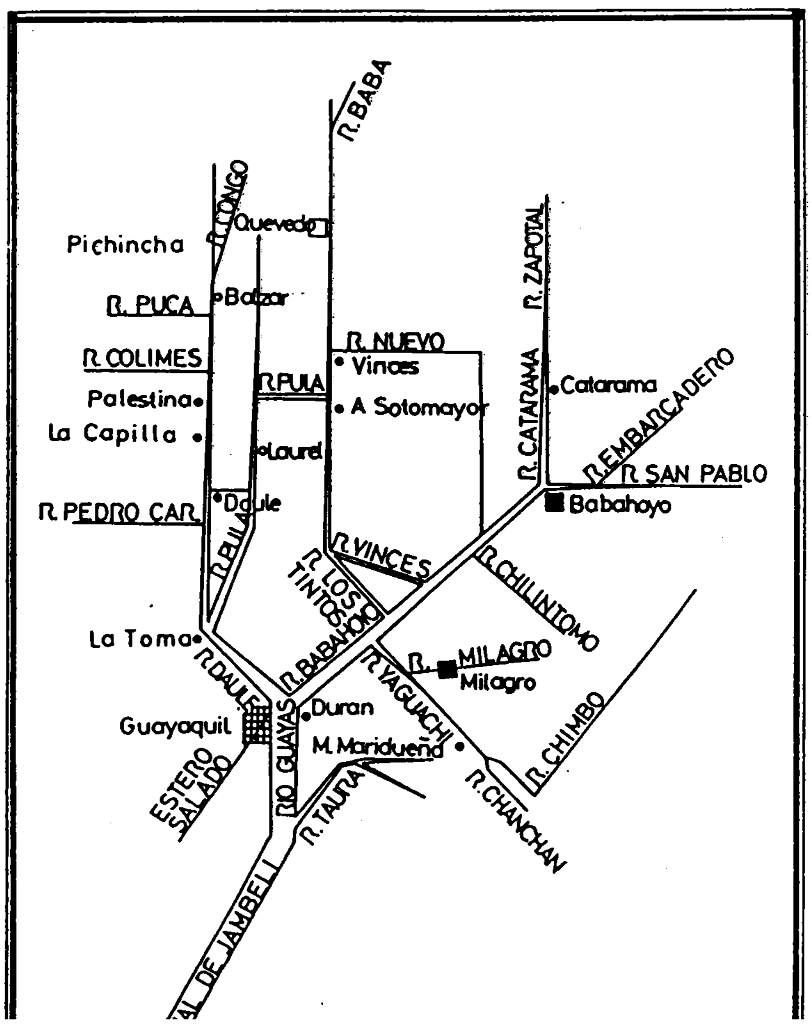
2. Domestic discharges from the towns in the Guayas River Basin.

The Guayas River Basin has a surface area of 34,000 km^2, making it the largest on the west coast of South America. Its tributaries cross fertile lands of agricultural importance. None of the numerous towns along the river banks treat their sewage, although a few have sewer systems (Table 3 and Figure 3). The waste waters from these towns increase the nutrient load in the rivers (Rendon, Padilla and Perez, 1983).

Table 3: Cities in the Guayas River Basin with sewers but without sewage treatment (from EMAG, quoted in DPAMG, 1986; BOD estimated at 25 kg/person/yr)

City	Population	BOD_5 (tons/year)
Babahoyo	28,345	708.6
Balzar	11,144	278.6
Catarama	--	--
Milagro	53,058	1,326.5
Puebloviejo	2,495	62.4
Quevedo	43,123	1,078.1
Ventanas	8,890	222.3
Vinces	9,717	242.9

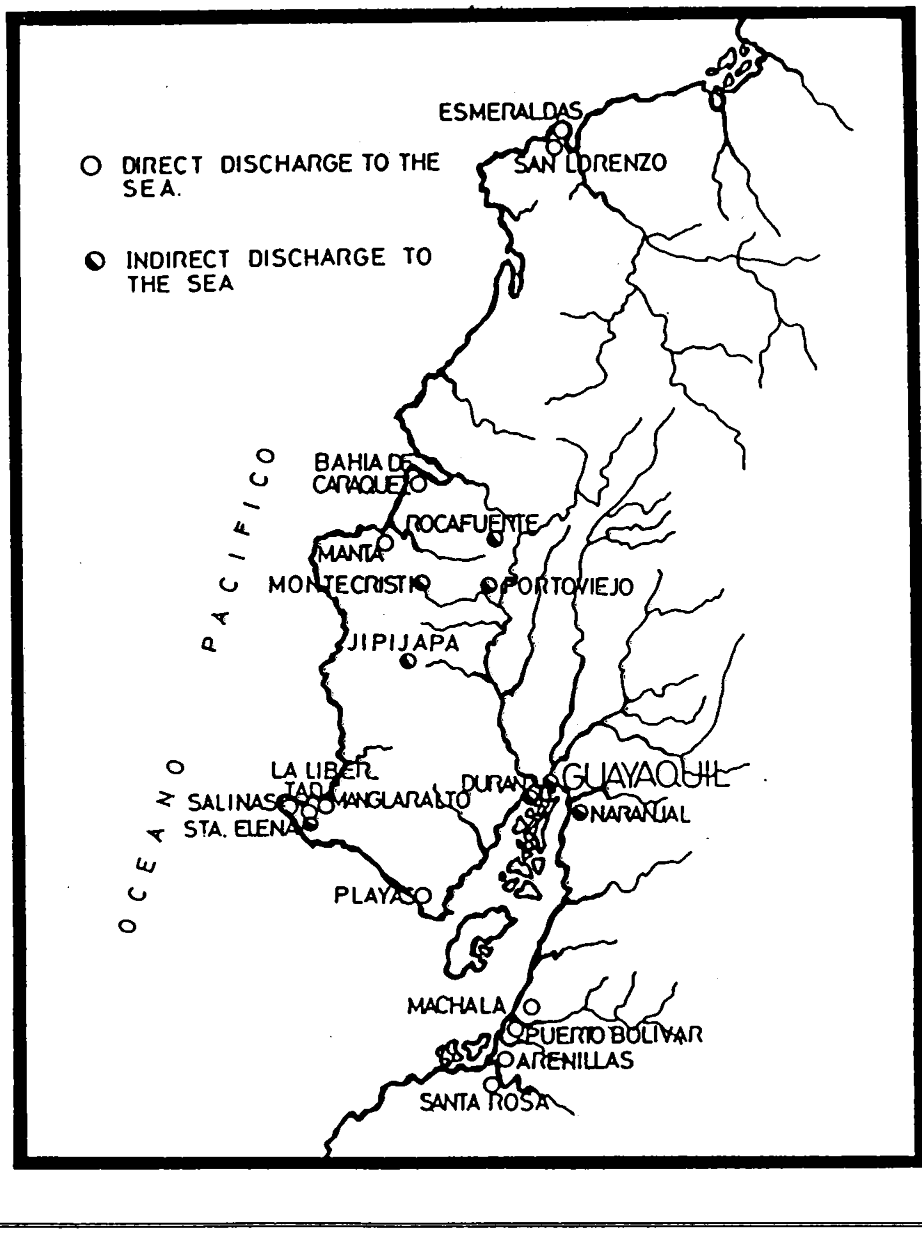
Figure 3: Towns of the Guayas River Basin



3. Domestic and industrial discharge from the principal coastal cities.

The population increase in cities bordering the seacoast, associated with urban development and migration from rural areas, has put pressure on the coastal waters in some areas. The wastes of these population centres are discharged into the waters with little or no treatment. The Ecuadorian Government is putting emphasis on solving the sanitation problems of all the cities. Some of them have sewer systems for sewage water and run-off, and all have septic tanks. Cities that discharge directly or indirectly into the sea are shown in Figure 4.

Figure 4: Cities discharging directly or indirectly into coastal waters



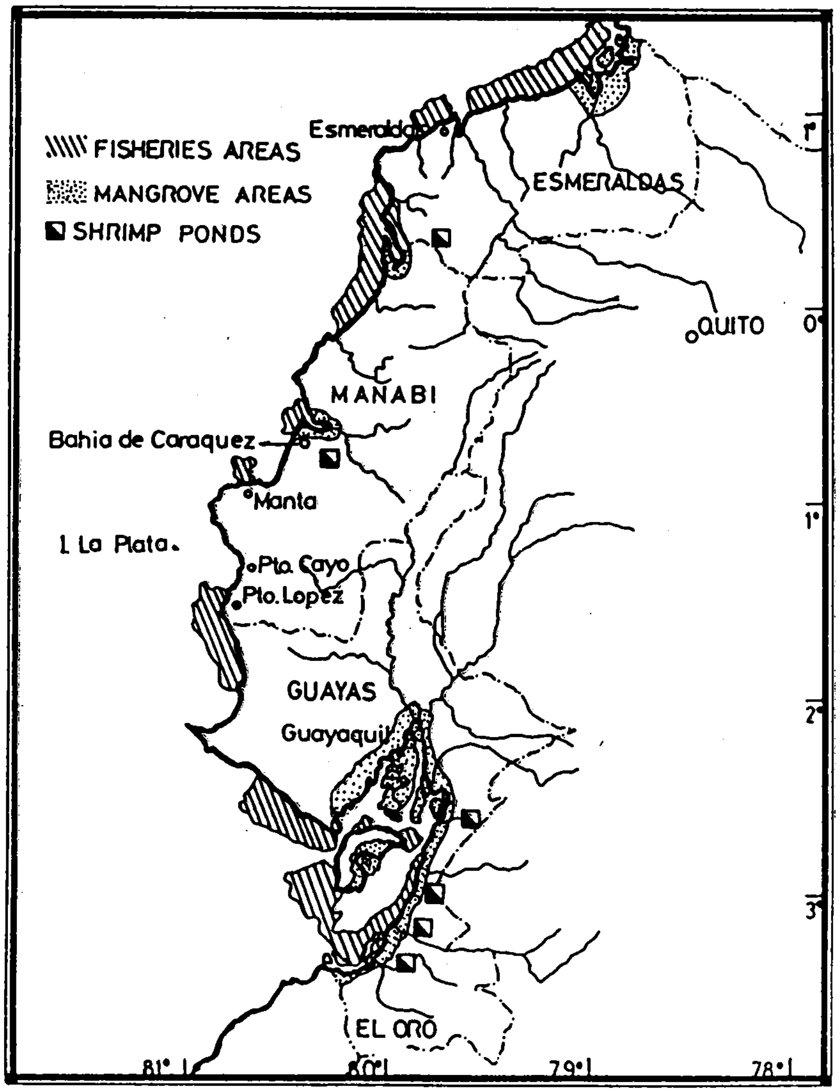
4. Effluents from food industries along the coast outside of Guayaquil.

The food industries in the towns along the coast are mainly concerned with fisheries resources. There are around 70, and very few treat their waste water before discharging it into the sea. The beaches next to these factories have a very bad appearance and a disagreeable smell. Swimming is prohibited in the waters in front of them.

5. Effluents from the shrimp ponds.

Mangrove areas are capable of supporting major fisheries. Numerous aquatic species of economic importance benefit from their high productivity. Ecuador has two principal mangrove forests: one in the north in the province of Esmeraldas, and the other along the margins of the Gulf of Guayaquil. The shrimp industry has developed next to the mangrove areas (Figure 5). The aquaculture of this crustacean is vital for the economy of the country because it produces more income than any other export product. Shrimp mariculture started in 1969 in the south of Ecuador with 600 ha of small ponds; by 1984, shrimp ponds had increased to 89,367 ha (Clirsen, 1985). The largest mangrove area is around the Gulf of Guayaquil where the shrimp industry is also best developed.

Figure 5: Mangrove, fisheries and shrimp pond sites in Ecuador



According to Twilley (1986), the exchange of sea water through the ponds, under semi-extensive mariculture, fluctuates between 3 and 8‰, increasing under more intensive farming. With the present operation of about 30,000 ha of ponds at a 5% pumping rate, the daily volume of water exchanged with the estuary is greater than the discharge of the Guayas River during low tidal flows. Conditions will become worse if the cultures are intensified. Twilley indicates that, if the number of ponds increases, the residual discharges will eventually lead to deterioration of the estuarine system.

6. Agrochemicals

Pesticide use in Ecuador has become common in agriculture over the last decade. The construction of the Daule-Peripa River Dam will stimulate the establishment of small farms which will use pesticides and fertilizers. This will obviously increase the run-off of these chemicals in the watershed of the Daule River. Rice is the principal cultivable crop in the area, followed by coffee and cacao (Arriaga, 1986).

7. Petroleum hydrocarbons

In 1972, Ecuador became an oil producing country, and since then it has been subject to traffic in oil and its products. Oil is mainly exploited in the north-east part of the country. It is transported by pipeline through the Andes to the Balao terminal, located in the estuary of the Esmeraldas River.

The total petroleum production and the amount exported are shown in Table 4. The crude oil is transported from the Balao terminal to other coastal cities by small ships with capacities between 17,000 and 31,000 tons. Oil spills in territorial waters amount to 10,000 barrels per year, due mainly to tanker accidents, bilge pumping at sea, tanker ballast, coastal refineries, terminal operations, etc. Pollution incidents during loading and unloading have been traced to improper coupling or uncoupling operations, broken hose lines, negligent handling of valves and shut-off, and overpumping.

Table 4: Volume of production and exportation of oil (from Eguez, 1987)

Period	Production (million barrels)	Export (million barrels)
1972-1979	516.62	409.7
1980-1984	409.71	248.1
1985	102.52	69.0
1986	104.60	72.2
TOTAL	1133.45	739.0

Ecuador has three refineries located on the coast: one next to the Balao terminal, the other two on the Santa Elena Peninsula. They are old-fashioned, and produce low octane gasoline. Tetraethyl lead is added to the gasoline in small quantities as an anti-knock compound (Table 5); when used in internal combustion engines, this gasoline releases lead into the air causing atmospheric pollution.

Table 5: Consumption of tetraethyl lead in Ecuador (from Quevedo y Medina, 1987)

Refinery	Consumption of lead (tons/month)
Estatal de Esmeraldas	69
Anglo	45
Repetrol	17

Principal polluted areas

According to previous studies, the most important polluted areas in the coastal water of Ecuador are Estero Salado, Guayas River, lower course of the Daule River, Esmeraldas River and Teaone River.

Estero Salado

This branch of the inner estuary of the Gulf of Guayaquil extends from the Canal del Morro inland to the south and west borders of the city of Guayaquil. It is 64 km long, with many branches with different names, such as Estero del Muerto, Estero Covina, Estero Chongon, etc. It receives a small amount of fresh water from the Guayas River through the Canal de Cascajal and Estero Covina, as well as from the city of Guayaquil, which discharges approximately 100 liters per second of sewage water (Arriaga, 1976). The surface salinity (1 m) usually exceeds 25 ppt, and reaches a maximum of 31 ppt near Canal del Morro. The inorganic nutrient levels (Ayarza <u>et al.</u>, in press) are:

phosphate:	4.9 to 33.4 µg-at PO_4-P/l
nitrate:	<0.05 to 18.0 µg-at NO_3-N/l
nitrite:	0.5 to 2.5 µg-at NO_2-N/l
ammonium:	5.2 to 114.0 µg-at NH_4-N/l.

The highest values of phosphate and ammonium are found in the urban section of the Estero Salado at low tide, associated with anoxic conditions and an absence of nitrate.

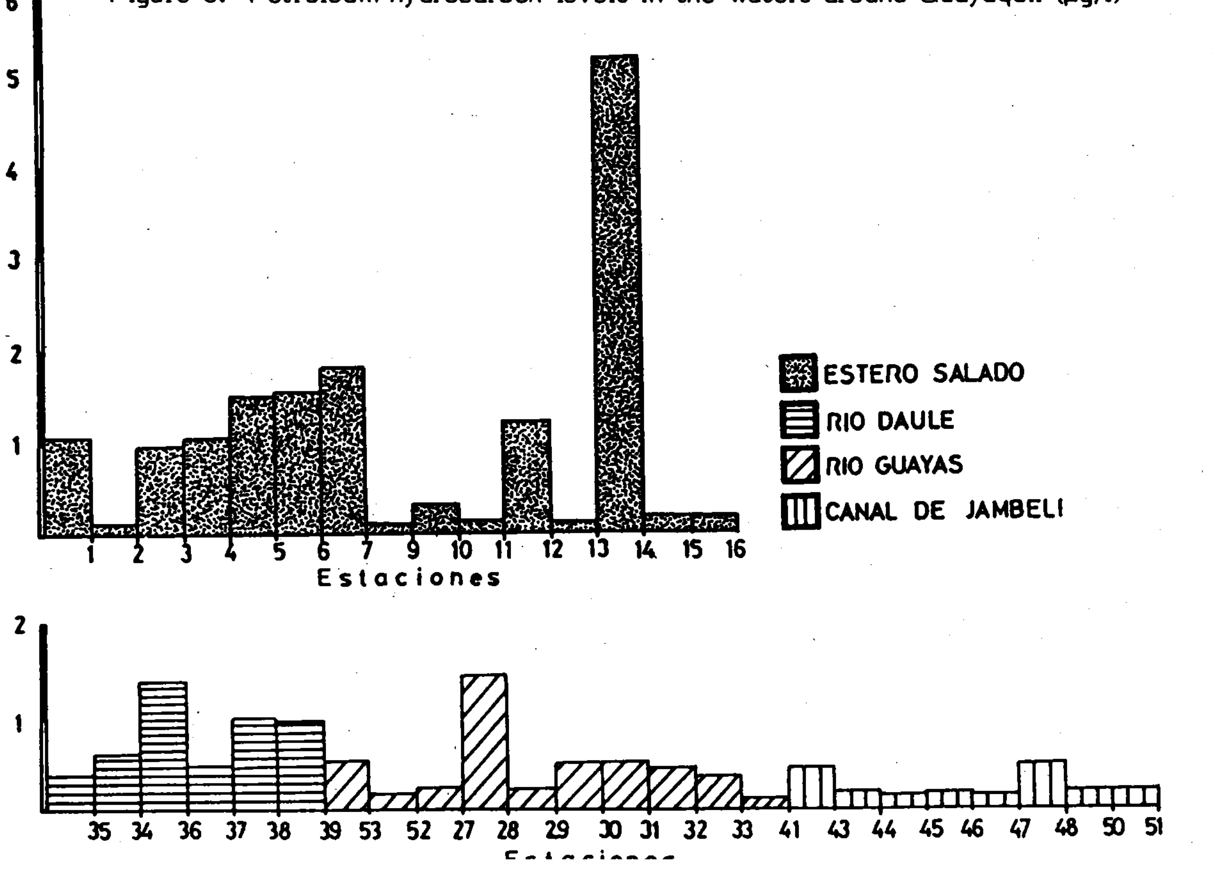
Along the margins of the Estero Salado, downstream from the city of Guayaquil, are more than 50% of the shrimp ponds of Ecuador. The impact of this industry on the water quality of the Estero has not been studied yet. However, the presence of surface nitrate at 8.4 to 17.0 µg-at NO_3-N/l and of dissolved organic nitrogen at 23.4 to 68.0 µg-at NO_3-N/l, quantities higher than those found in the urban section of the Estero (Ormaza, unpublished data), is a sign of eutrophication that may be a consequence of the effluents discharged from the shrimp ponds.

The amounts of trace metals found in the sediments of the urban area include:

copper:	65.0 to 799.5 mg/kg (dry weight)
cadmium:	0.5 to 3.2 µg/kg (dry weight)
iron:	0.56 to 2.93 g/kg (dry weight).

The analyses of petroleum hydrocarbons show levels below 2.0 µg/l for all areas from the Canal del Morro to the city of Guayaquil (Solorzano, 1986), except were there was spillage from commercial vessels (Figure 6). However, the oil terminal for commercial shipping is in a branch of the Estero known as Estero del Muerto, and there the Division of Chemical Oceanography of the Instituto Oceanografico de la Armada (1985) found values above 30 µg/l.

Figure 6: Petroleum hydrocarbon levels in the waters around Guayaquil (µg/l)



Guayas River and lower course of the Daule River

The Guayas River is 70 km long and discharges around 30,000,000 m^3 of water per year into the Gulf of Guayaquil. It is formed by the Daule and Babahoyo Rivers, which join in the northern part of Guayaquil. The sewage from the city is discharged into the Guayas River through two underwater pipelines that drain the sewage from the northern and southern sections of the city.

The Daule River is the largest in the Guayas River Basin. Before joining the Babahoyo River it crosses 250 km of fertile land. The water of the upper course of the river is fit for human consumption, and will feed the reservoir of the Daule-Peripa Dam. The water of the middle and lower courses of the river are unfit for human use without pretreatment. In this section at La Toma, water is removed and treated for distribution to the city of Guayaquil. The lower course is contaminated by effluents from the nearby industries. Tidal movements also cause some water exchange between the Daule and Guayas Rivers.

The surface concentration of phosphate in the Guayas River ranges from 2.0 to 6.0 µg-at PO_4-P/l, with the highest values near the sewage outfall. Surface values of nitrate are 10.0 to 50.0 µg-at NO_3-N/l, and of dissolved organic nitrogen 40.0 to 60.0 µg-at NO_3-N/l (Valencia, 1986). In the Daule River, surface measurements show nitrate at 35.0 µg-at NO_3-N/l, nitrite 2.5 µg-at NO_2-N/l, and ammonium 3.0 µg-at NH_4-N/l (Empresa Municipal de Alcantarillado, 1980).

With respect to trace metals, surface copper values are variable in both rivers, fluctuating between 22.0 and 100.0 µg Cu/l. Cadmium levels in the Guayas and Daule Rivers are between 0.10 and 3.45 µg Cd/l. The value of 0.10 µg Cd/l was found in the Daule River at Toma, location of the intake for the Guayaquil water supply. Close to the northern sewage outfall, Perez (1985) found around 14.0 µg Cd/l, exceeding the permissible limit for aquatic life (Ketchum, 1975).

The analyses of petroleum hydrocarbons in the Guayas and Daule Rivers give values below 2.0 µg/l, with the lowest values in the Guayas River. Only when samples are taken near spilled oil do the values rise to 3-5 µg/l.

There are few data for pesticide levels in the Daule River. DDT, Aldrin, Chlordane, Mirex, Lindane, Dieldrin and heptachlorine have been found in negligible amounts in the water column (Paladines, unpublished data).

Esmeraldas and Teaone Rivers

The Esmeraldas River is 330 km long and passes by the city of Esmeraldas with 26,561 inhabitants. The Teaone River is a tributary of the Esmeraldas, and is next to the site of the largest oil refinery in the country, which drains its poorly-treated waste water into the river, producing serious changes in the water chemistry.

In the Esmeraldas River, surface concentrations of phosphate are 0.9 to 7.5 µg-at PO_4-P/l, nitrate 0.5 to 29.3 µg-at NO_3-N/l, and ammonium 0.8 to 117.4 µg-at NH_4-N/l. The highest value came from the point where the Teaone River empties into the Esmeraldas (Rendon, Chalen de Padilla and Perez, 1983). Surface values in the Teaone River are: phosphate 1.60 to 10.60 µg-at PO_4-P/l and nitrate 0.05 to 34.60 µg-at NO_3-N/l. The values for ammonium are always very high; Rendon et al. (1983) found a range between 7.2 and over 30.0 µg-at NH_4-N/l.

With respect to petroleum hydrocarbons, the spills in the Esmeraldas River are accidental, while in the Teaone River they are due to bad operation of the refinery. Analyses carried out by Valencia (1986) showed values exceeding 50 µg/l.

Conclusions

Pollution in Ecuador is limited to small areas of the Pacific coastal waters. Among the cities of the country, Guayaquil is the biggest source of pollutants.

Nutrient levels in the waters studied indicate that eutrophication is occurring. According to Ayarza et al. (in press), adsorption and denitrification may be taking place in the sediments of the urban section of the Estero Salado, which would decrease the level of eutrophication in its waters. The shrimp ponds along the Estero Salado may be the source of its high values for dissolved organic nitrogen. In the Guayas River, the high levels of phosphate and nitrate in the vicinity of the outfall suggest a domestic origin for these compounds. The extremely high levels of ammonium in the Teaone River indicate bacterial decomposition of the organic matter present in the waste water from the refinery. Sewage from the city of Esmeraldas may contribute to the nutrient values encountered in the Esmeraldas River.

Copper concentrations in the Guayas and Daule Rivers exceed the level considered harmless for living organisms (Ketchum, 1975). According to Richards (1965), the metals tend to complex with organic matter present in an aquatic medium. The high levels of organic substances present in the domestic sewage may decrease the toxicity of the copper ions by forming organo-metallic compounds. Metals are also adsorbed by the silt present in river water; this may happen in both rivers since they are rich in silt. This would decrease the toxicity of the metals by settling them out and burying them in the bottom sediments. Most of the cadmium values are below 10 µg/l; the one value of 14 µg/l may be associated with industrial effluents from the city.

The levels of petroleum hydrocarbons found in the water of the Estero Salado and the Guayas and Daule Rivers are not dangerous for the biota. Oil pollution in Ecuador occurs in those areas with oil terminal operations, and in cases of accidental spills by commercial ships.

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SURVEY AND MONITORING OF MARINE POLLUTION IN PERU

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ABSTRACT

This paper summarizes studies of marine pollution along the Peruvian coast by several institutions participating in the Action Plan. Among the results reported, the Lima-Callao area, with a total of 1,047 industries inventoried, was shown to discharge 16 to 18 m^3/sec. of domestic and industrial wastes into the marine environment, amounting to a BOD_5 of 85,449 tons/year, and producing summer levels of total coliforms of 28,000 MPN and fecal coliforms of 5,000 MPN. The Pisco area has an underwater marine outfall for domestic and industrial wastes, as well as direct discharge into the sea of fishing industry wastes. Biological indicators for heavy metals showed the highest concentrations in areas where there are tailings discharges or industrial wastes, but usually within permissible levels. Oil pollution monitoring at Callao has shown maximum values of 1.47 µg/l and 0.85 µg/l in areas close to the Pampilla and Conchan refineries.

Introduction

The coast of Peru is 2,864 km long, with a population of 8,074,977 in 1981 expected to reach 15,448,300 in the year 2000. There is marine pollution in spite of present legislation and the development of programmes to protect the coastal marine environment. Research on different aspects of marine pollution, including heavy metals, oil, and ecological and faunal effects, has been carried out by Avila (1971), Guillen (1973), Malnatti (1973, 1976), Echegaray and Chang (1974), Valcarcel et al. (1974), Guillen and Aquino (1978), and Guillen et al. (1978, 1980).

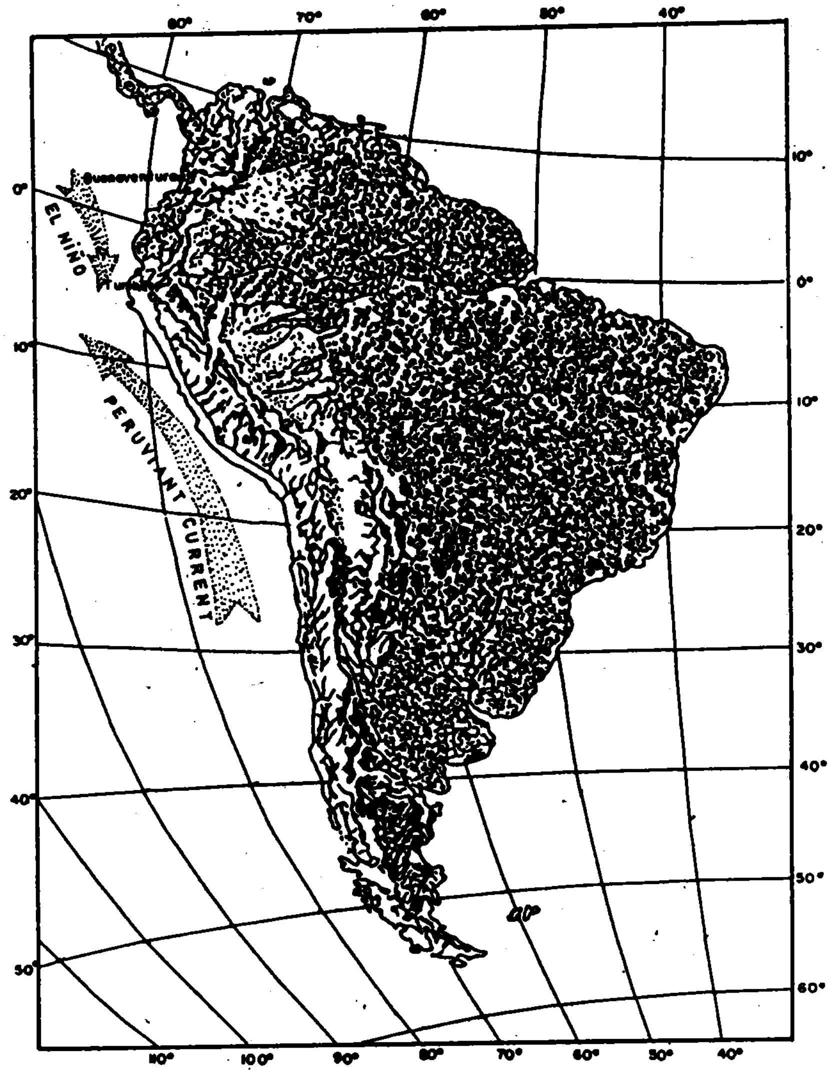
Research on marine pollution under the Action Plan started in Peru in 1984 through programmes co-ordinated by the CPPS with support from UNEP. These include monitoring and control of marine pollution by petroleum hydrocarbons by the Institute of the Sea (Instituto del Mar del Peru -IMARPE), characterization and monitoring of marine pollution from domestic, agricultural, industrial and mining sources by institutions such as the Hydrography and Navigation Directorate of the Peruvian Navy, the Institute of the Sea, and the Ministry of Health, and monitoring marine pollution through biological indicators (bivalve molluscs) by Federico Villarreal University.

Climatic and oceanographic conditions along the Peruvian coast

Peru is located on the west coast of South America in the tropics between 3° and 18° south latitude. However, unlike most hot humid tropical zones, the Peruvian coast consists of a long desert from 4° south to 25° south in central Chile. The dry weather on the northern coast of Peru, such as at Tumbes with 10 mm annual rainfall, contrasts sharply with the Colombian Pacific coast only 900 km to the north with annual rainfall of 800 mm (Figure 1). This particular climate is due to a combination of factors including the cold Peruvian Current, the Andean mountain range, the coastal upwelling, and atmospheric subsidence.

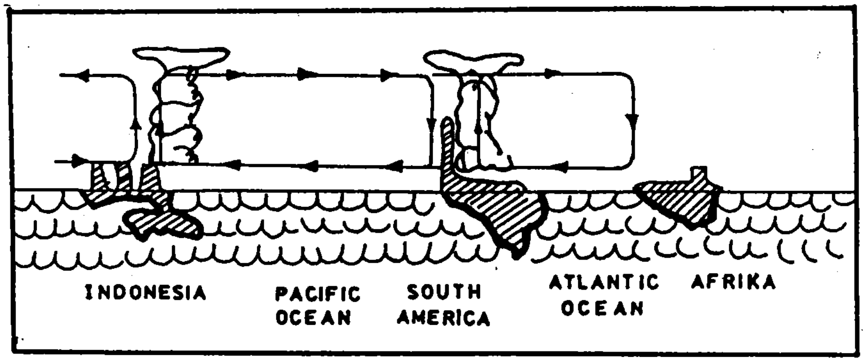
The Peruvian coast has a dry coastal climate because it is protected from continental influences such as the humidity of the Amazon Basin by the high mountains of the Andes and by the orientation of its coastline almost parallel to the surface trade winds. This climate is

Figure 1: South America with mean Pacific Ocean currents



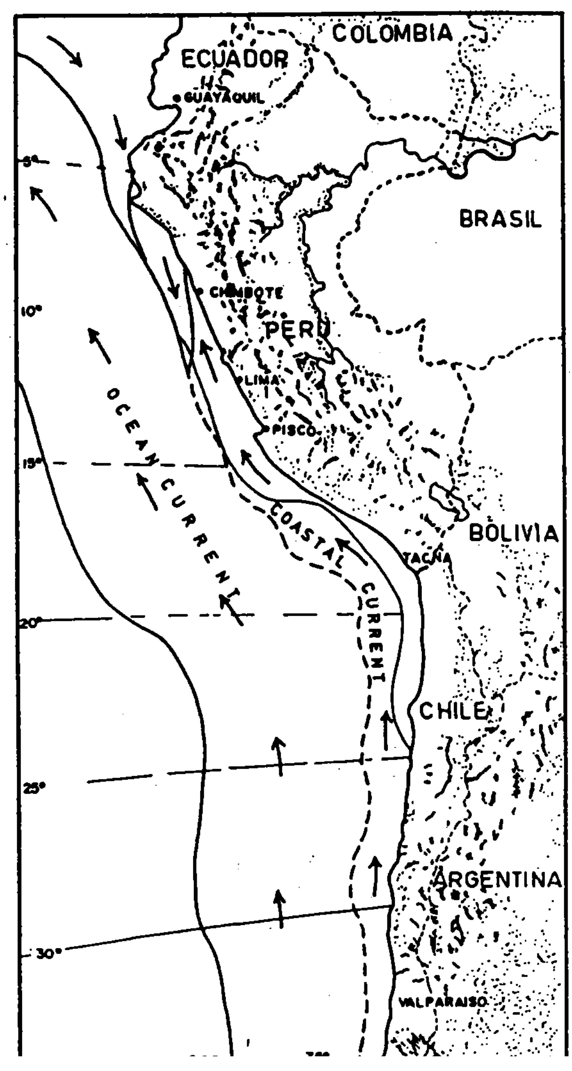
characterized by cool to moderately warm temperatures, relatively high humidity, seasonal rainfall only on the northern coast, and a sky covered with low clouds almost all year long. The surface temperature of the water off the Peruvian coast is low, producing little evaporation and thus little atmospheric precipitation. A permanent thermal inversion in the first thousand metres above the Peruvian coast is maintained in summer by the low temperature of the sea, and in winter by the trade winds. It controls the weather and climate of the western slope of the Andes by preventing the vertical exchange of air masses between the maritime layer and the rest of the troposphere, resulting in a dense and almost permanent layer of stratus cloud at 300 to 900 meters altitude. The atmospheric subsidence (descending air) on the Pacific west coast is part of the general atmospheric pattern known as Walker's circulation (Figure 2). This phenomenon produces a relative warming in the lower coastal atmosphere which interacts with the low sea temperature.

Figure 2: Walker's circulation



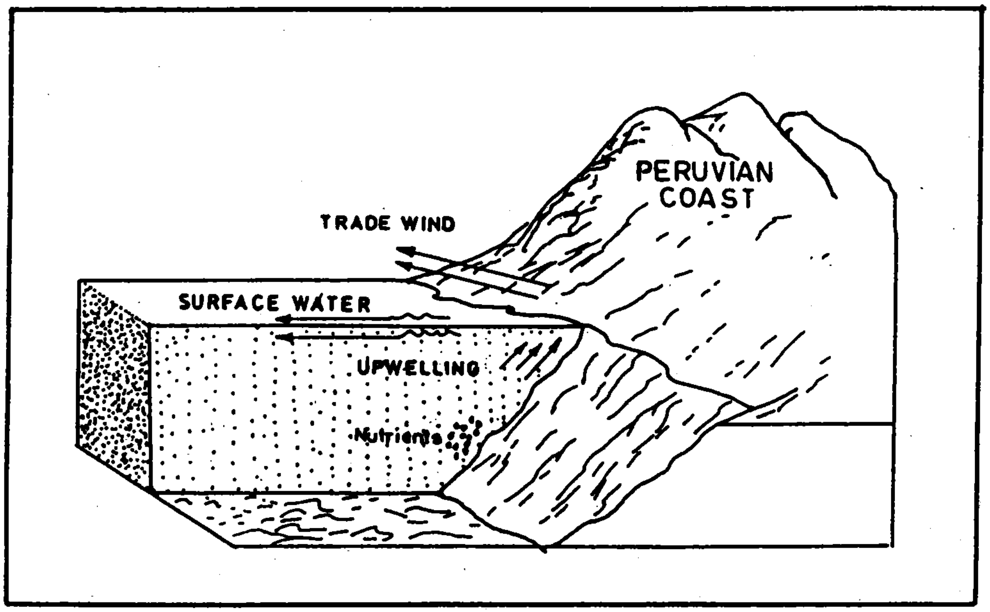
The oceanographic influences on the climate are mostly related to the Peruvian (or Humboldt) Current, which is a cold mass of water that flows north from the Antarctic, skirting the central coast of Chile and the Peruvian coast to Punta Aguja (5° south) where it turns northwest to become the South Equatorial Current. The Peruvian Current has two components. The Coastal Current flows close to the coast at a speed of 0.2 to 0.3 knots, before increasing to 0.5 to 0.7 knots when it becomes the South Equatorial Current. Along the coast of Peru the current is stronger from April to September than during the rest of the year (Wyrtki, 1965; Figure 3). The Oceanic Current flows far from the coast, and thus has less effect on the climate. Between these two currents is the Peruvian Countercurrent, which is usually subsurface and only occasionally comes to the surface (Wirtki, 1965).

Figure 3: The Peruvian Current



There is a very strong coastal upwelling bringing deep cold water up to the surface, where it supports a special ecological regime with abundant marine life. The upwelling is caused by the trade winds blowing on the south and south-east coast and displacing the surface waters to the west (the Ekman effect) thus causing colder water to rise to the surface (Figure 4).

Figure 4: Upwelling along the Peruvian coast



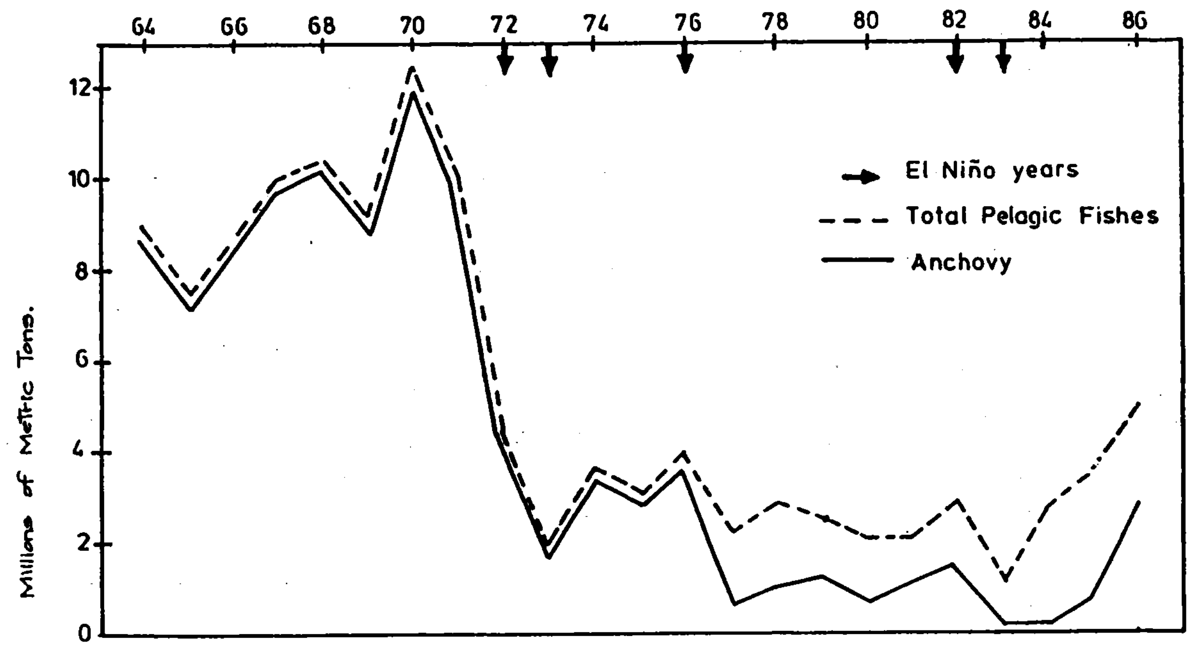
The "El Nino" phenomenon is a temporary change in the normal conditions along the Peruvian coast described above, in which a mass of equatorial water invades the northern region of Peru, transforming the desert environment with tropical rainfall appropriate to the latitude. The phenomenon, which has global effects, appears with a frequency of from 4 to 11 years, sometimes with great strength as in 1982-83; it is very harmful to Peruvian agriculture and fishing.

Geographically, the most important determinant of Peruvian coastal conditions is the Andes mountain range, which forms an enormous barrier behind the narrow coast, which ranges from 20 to a maximum of 100 km wide. The high winds that parallel the coast also favour the coastal upwelling that regulates the weather.

Peru has both industrial-scale pelagic and demersal fisheries, and individual coastal fishing activities which provide products for direct human consumption by coastal, and sometimes mountain, inhabitants. The pelagic fisheries began in the 1940's, when the first fish meal processing plants were established to use the by-products of tuna, swordfish and bonito. These plants also started processing anchovies, but it was only in 1957 after the collapse of the California sardine fishery, that the number of factories was increased and anchovy exports intensified. The fishing industry reached its height in the 1960's, with up to 12 million tons of anchovies alone caught in 1970. However the 1972 "El Nino" damaged the pelagic fishery and reduced the catch to one quarter of its former size (Figure 5). At the same time, there was an increase in other fish such as sardine, jack mackerel and chub mackerel. The demersal fishery is based mainly on hake, and reached its height in 1978 when the catch topped 300,000 tons.

The "El Nino" phenomenon of 1982-83, among the strongest of the last fifty years, caused great damage in Peru to the fishery for pelagic resources, but it did not hurt demersal fishing or benthic resources in general. Thus, among the shellfish, there was rapid growth of the scallops in the Independencia Bay area near Pisco (13°47'S), allowing the harvest of volumes up to 25,246 tonnes in 1983 in comparison with the highest previous catch of 84 tonnes in 1981.

Figure 5: Annual landings of anchovies and total pelagic fishes (from IMARPE, 1987)



Programme to assess pollution sources along the coast of Peru

Peru takes part in the regional programme to characterize and control marine pollution from terrestrial sources. A survey of the sources, levels and effects of marine pollution in the South-East Pacific by the CPPS, including Peru (Guillen, 1981), identified an area with heavy pollution: Callao Bay and the coast of Lima, and one with medium problems: Pisco Bay. In these two areas, a study was started in 1986 to inventory and characterize the marine pollution from domestic, industrial and mining sources.

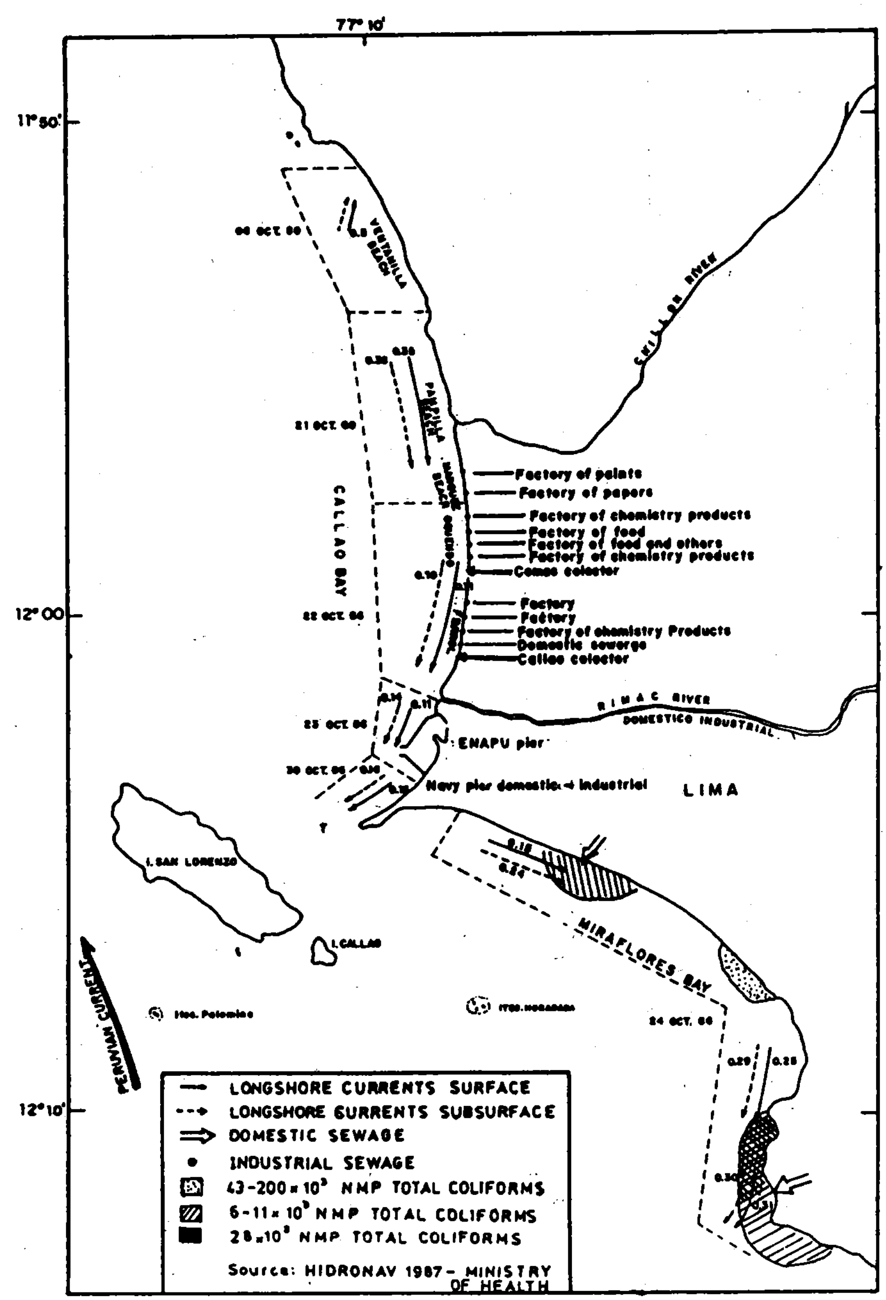
Domestic, industrial and mining pollution in Lima-Callao

Lima, the capital of Peru, is on the central coast (12°S), on the great flood plain of the Rimac River, whose mouth is close to Callao, the most important port in the country. Callao Bay on the north coast of Lima includes the mouths of the Chillon and Rimac Rivers, with the city of Callao between them, and the beaches of Ventanilla, Pampilla (where the oil refinery is located), Marquez and Oquendo. Callao Harbour is at the southern end of the bay near La Punta Peninsula. Miraflores Bay on the south side of Lima is characterized by its surrounding cliffs and its sand and smooth pebble beaches.

DOMESTIC EFFLUENTS. The Lima-Callao area had 4,608,010 inhabitants in 1981, or 27.2% of the population of Peru, and it is projected to grow to 8,652,700 by the year 2000. Water and sewerage are provided by a state enterprise. Water from the Rimac River is treated to provide 15 cubic metres per second to the city water supply. There are 300 wells in different parts of the city that give 9 cubic metres per second more. However, only 17 of the total 24 cubic metres per second go into the sewage system.

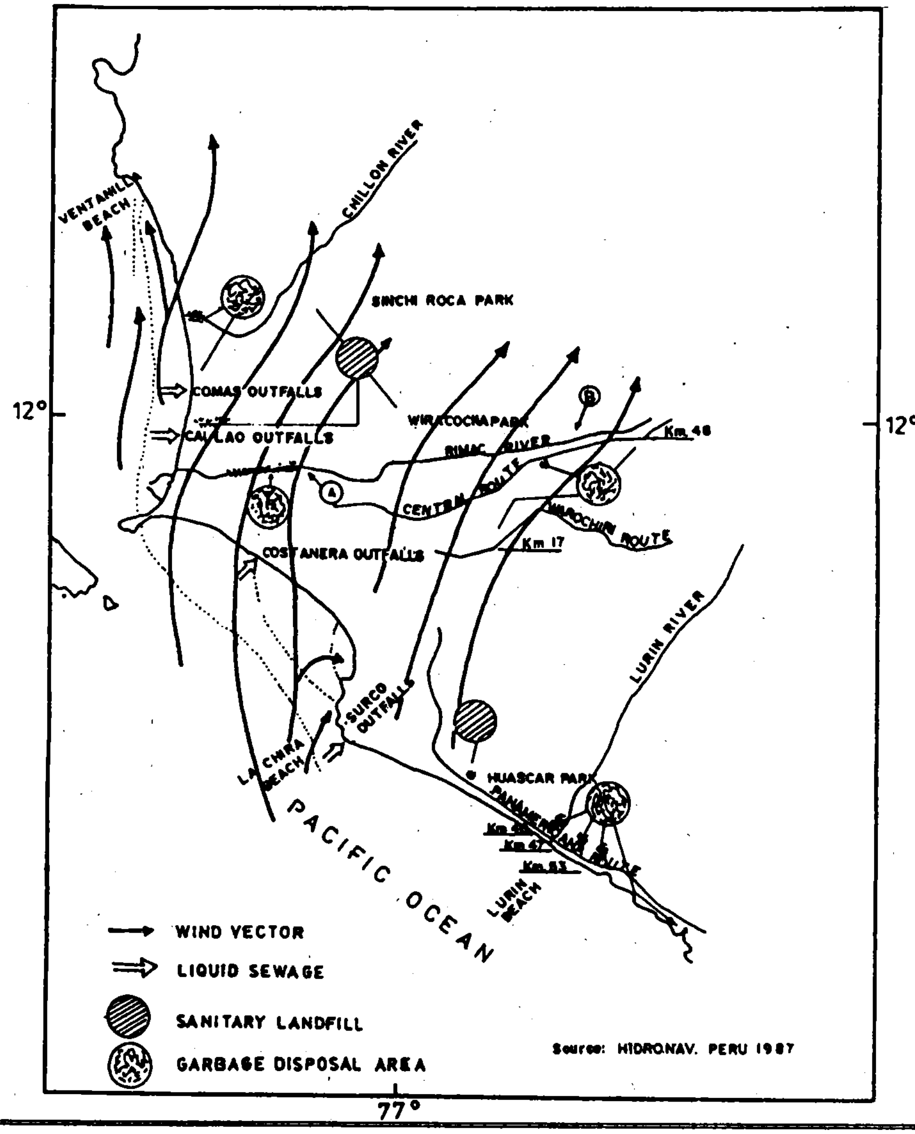
Treatment of domestic effluents is inadequate, and they contain high levels of BOD_5, suspended solids, microorganisms and nutrients. The pollution load reaching the aquatic environment includes a BOD_5 of 85,449 tons/year, COD of 192,084 tons/year, suspended solids of 105,612 tons/year, and phosphate 2,280 tons/year. Figure 6 shows the outfalls for domestic/industrial effluents in the Lima-Callao area. These include the four outfalls of the sewage system (Comas, Callao, Costanero and Surco); 16 outfalls of lower volume, mostly of industrial origin; and the Chillon and Rimac Rivers. There is high microbial pollution in both Callao and Miraflores Bays in the summer, with total coliforms ranging from 28,500 to 199 MPN, affecting the thousands of swimmers who go to the beach (Figure 6). The highest counts are from Herradura Beach, where February 1987 water analyses gave 43 to 93,000 MPN of faecal coliforms (DITESA, Ministry of Health, 1987), although some beaches had counts as low as 3 to 43 MPN.

Figure 6: Sources of industrial and domestic effluents into Callao and Miraflores Bays (bacteriological data from February 1987)



Solid waste production in Lima and Callao is estimated at 0.81 kg per inhabitant per day for domestic refuse, plus solid wastes from the markets, big stores, public and private institutions, and industries. Collection is the responsibility of the municipal service in the 46 districts, and the enterprise that runs the sanitary land fill. There are 3 sanitary land fills and 11 garbage disposal areas (Figure 7). Of the 4,800 tonnes/day of solid wastes generated, 80% is gathered by the urban collection service and 20% is burned.

Figure 7: Solid waste disposal sites and sewage outfalls in the Lima area



INDUSTRIAL POLLUTION. Agro-industrial development accelerated in Peru beginning in the 1950's, mainly on the coast. The neglect of the mountain and jungle regions led to a 1959 policy of decentralization and industrial promotion in the interior, with the creation of industrial parks in cities such as Chiclayo, Chimbote, Cuzco, Huancayo, Pasco, etc. As a result the percentage of industries concentrated in Lima-Callao decreased from 85% to 69% in 1979 and to 65%, or 14,290 industries, in 1986 (Table 1).

Table 1: Growth in the number of industries in Peru
(Source: Ministry of Industry, Commerce and Tourism, 1986)

Year	Lima-Callao	Coast	Andean area and jungle	Peru Total
1977	6277	1367	1269	8913
1978	6393	1533	1346	9272
1979	6502	1639	1490	9631
1980	6859	1790	1598	10247
1981	7198	1883	1689	10770
1982	7618	1913	1715	11246
1983 (est.)	7920	2206	2128	12254
1984 (est.)	8254	2285	2157	12695
1985 (est.)	10155	2812	2659	15623
1986 (est.)	14290	3957	3738	21985

These enterprises require connections for water and sewer services, unless they have their own wells. To evaluate the pollution generated by industrial activity, an inventory was made of 1027 industries (Table 2), and the liquid effluents from some food and fish processing and chemical industries were analysed (Table 3). The main outfalls, which include industrial as well as domestic wastes, drain 16 to 18 cubic metres/second of waste waters into the marine environment, up from 12 cu. m/sec in 1981 (Guillen, 1981).

Table 2: Industrial inventory of Lima
(HIDRONAV, 1987)

N°	Type of industry	Amount
1	Agro industries	40
2	Food manufacturing	157
3	Beverage industry	42
4	Tobacco industry	2
5	Textile industry	103
6	Leather	47
7	Wood and wood products	17
8	Pulp and paper	55
9	Basic industrial chemicals	308
10	Non-metallic industry	71
11	Basic metal industry	41
12	Fabricated metal products	142
	TOTAL	1025

Table 3: Effluents from domestic and industrial sources into Callao and Miraflores Bays
(from HIDRONAV, 1987)

Source	Waste volume (l/sec)	Conductivity (μohm/cm^2)	T°C	pH	SS	BOD_5	O_2	Nitrate
DOMESTIC SOURCES								
Surco outfalls	7150	386	22.2	6.0	1979	296.6	-	0.199
Costanero outfalls	1938	843	21.4	7.0	2046	86.6	0.00	0.214
La Perla outfalls	-	856	22.7	7.0	458	69.0	0.90	-
Other outfalls	360	-	27.8	-	301.0	9.38	1.61	-
Comas outfalls	1635.0	610	21.8	7.0	352.0	99.90	0.0	0.190
Callao outfalls	862.2	497	24.3	7.0	1594	99.6	0.00	0.145
Navy Pier outfalls	17.7	796	22.4	7.0	83	6.46	2.96	0.148
FOOD INDUSTRIES								
Food factory A	0.13	942	19.0	7.0	1403	7.54	2.42	0.286
Food factory B	2.6	1452	25.8	2.0	2257	6.84	7.62	0.807
CHEMICAL INDUSTRIES								
Chemical factory A	304.3	397	22.0	7.0	267	10.2	0.00	0.139
Chemical factory B	172.0	936	30.5	3.5	449.0	0.00	0.00	0.259
Chemical factory C	39.2	-	24.8	0.5	10.2	5.72	6.58	0.193
Chemical factory D	10.8	648	27.6	6.5	434	23.11	3.11	0.272
Chemical factory E	8.2	600	26.1	6.5	425	41.81	3.22	0.095
FISHERIES INDUSTRIES								
Fish meal/oil factory A	126.0	853	33.5	7.0	210	43.00	3.23	0.142
Fish meal/oil factory B	584.3	649	28.5	6.5	1700	60.80	0.00	0.188
Fish meal/oil factory C	175.5	1704	23.6	6.0	601	101.40	0.00	0.292
Chillon River	138.4	497	22.2	6.0	244	42.20	2.20	0.216
Rimac River	3656.0	630	20.8	6.0	449	39.80	0.80	0 .185

MINING POLLUTION. Mining is extensive in Peru on the western slopes of the Andes. Most of the tailings produced by the extraction and concentration of minerals are discharged into the rivers which transport the mud and dissolved material to the marine environment. High above Lima, at an elevation of 2,350 to 4,500 metres, there is intense mining with 11 concentrating plants. The plants produce an average of 352 tons/day of mineral concentrate, particularly sulphides of lead, copper, iron, zinc and silver. Liquid effluents from seven important mining companies amounting to 13,725,164 cubic metres/year drain into the Rimac River. The Ministry of Health now monitors the river for toxic heavy metals monthly at several points, giving the results in Table 4. The levels of lead at 0.10 mg/l and of iron at 0,30 mg/l exceed the permissible levels established in the General Water Law of Peru.

Table 4: Heavy metals in the Rimac River
Four month average, October 1986-January 1987, in mg/l
(Source: Ministry of Health, Peru, 1987)

	Station A (6 samples)		Station B (5 samples)	
	Mean	Range	Mean	Range
Cu	0.054	0-0.145	0.038	0-0.08
Cd	0.007	0-0.02	0.	
Pb	0.117	0.012-0.250	0.	
Zn	0.420	0.040-1.217	0.230	0.050-0.350
Fe	0.648	0.18-1.217	1.870	0.93-3.80

For locations of Stations A and B, see Figure 7.

Domestic, industrial and mining pollution in Pisco Bay

Pisco Bay is located on the south coast of Peru (13°47'S; Figure 8) in a typical region of marine desert ecology resulting from the interaction of the cold Peruvian Current and the wide desert of Pisco. The mornings are cool and calm, while in the afternoon, a strong wind "Paracas" can reach 28 knots. The result is a bay rich in marine life, including fish, fur seals, sea birds and a great variety of shellfish. The Pisco River which empties here has created a wonderful valley producing quantities of cotton and grapes. Thus the 90,000 persons in Pisco City on the bay are supported by fishing and agriculture.

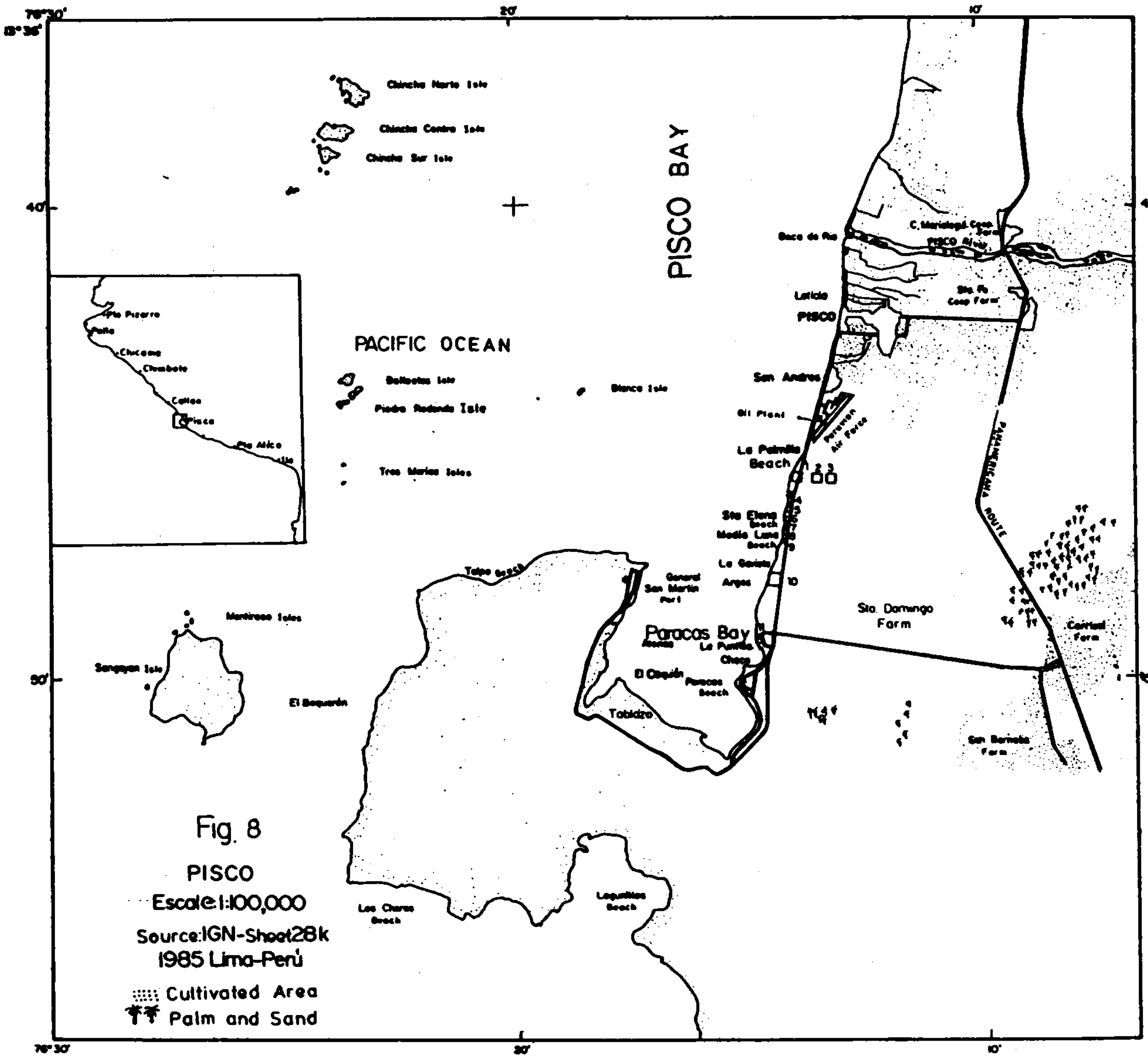
DOMESTIC AND INDUSTRIAL POLLUTION. Pisco city has a combined sewage system for domestic and industrial waste which flows out on the northern city limit through a submarine outfall 300 metres seaward and 80 metres deep with a discharge volume of 80 litres/second (SENAPAP, 1986). The main direct industrial discharge into the sea comes from the fishing industry whose plants are located on the southern coast of the bay on the way to the summer tourist resort of Paracas. Almost none of this effluent of 7,373 cubic metres/day receives treatment before discharge. Solid wastes from the city average 1,440 tons/year, and are disposed of at a site 6 km from the city for lack of a sanitary landfill. Bacteriological analysis of coastal water at the submarine sewage outfall and 200 and 400 metres from it showed highest values of 460 MPN total coliforms and 14 MPN faecal coliforms, indicating that the crowded swimming beaches have no coliform pollution problems.

MINING POLLUTION. There are two copper mines in Pisco province that discharge their tailings into the Pisco River at a volume of 1,302,000 cubic metres/year. Analyses of heavy metals and other chemical parameters at Paracas Beach and Punta Ripio in Paracas Bay (Figure 8) are shown in Table 5. The Punta Ripio sampling site is very close to San Martin Port in Pisco and to some areas used for scallop mariculture.

Table 5: Heavy metals and other oceanographic parameters from Pisco Bay
(Source: Jacinto and Sanchez, 1986)

Station	Cu mg/l	Zn mg/l	T°C	O_2 mg/l	Nitrate µg-at/l	Silicates µg-at/l	Sulphide µg/l
Punta Ripio M4	0.08	0.01	15.4	2.65	6.58	23.78	0.07
Paracas Beach M5	0.03	0.03	18.2	4.09	0.35	5.72	0.09

Figure 8: Pisco Bay



Bivalve mollusc monitoring for heavy metals

Heavy metals such as mercury, cadmium and copper are toxic for aquatic organisms. Since the Peruvian coastal waters receive tailings and other discharges, a monitoring programme for heavy metals in bivalve molluscs was begun in 1984 in the affected areas, with special emphasis on molluscs used as food. Bivalve molluscs such as the scallop Argopecten purpuratus, the mussel Aulacomya ater, the clam Gari solida, the donax Donax asper, etc. form shoals along the Peruvian coast and are exploited by small-scale fisheries.

Shellfish from different areas have been analysed for trace metals (Table 6). Mean mercury levels include 4.3 ng/g for clams from Pisco and 114.3 ng/g for mussels from Chimbote; scallops had low levels in all three areas sampled. Values for copper were below permissible levels, with the highest concentrations at Ite in Tacna where tailings from two copper mines in the Moquegua mountains come down by the Locumba River and enter the sea causing ecological damage. Sea water from this area has mean copper levels of 21.1 ppb (Jacinto, 1986), which is higher than the 9.73 ppb recorded for Callao by Guillen et al. (1978). Cadmium was generally low in the shellfish, but mussels from Chimbote averaged 4.72 µg/g, which exceeds the permissible concentration of cadmium of 2 µg/g wet weight (Nickless et al., 1972).

Table 6: Heavy metal concentrations in bivalve molluscs on the Peruvian coast (from Echegaray et al., 1986)

Species/Sites		Length (cm)	Hg (ng/g) Mean	Hg (ng/g) Range	Cu (µg/g) Mean	Cu (µg/g) Range	Cd (µg/g) Mean	Cd (µg/g) Range
Argopecten purpuratus								
Chimbote (9°S)	CH1	3.9- 7.2	6.9	4- 12	-		-	
Callao (12°S)	C1	3.6- 7.3	29.8	14-125	-		-	
	C2	5.7- 6.8	2.9	1- 5	-		-	
Pisco (13°S)	P1	7.5-11.0	11.0	2-124	-		-	
	P2	4.7- 7.8	42.2	2-124	0.58	0.01- 1.03	2.70	1.31-3.41
Aulacomya ater								
Chimbote	CH1	1.2- 6.2	82.3	30-113	1.31	0.83- 2.55	2.92	1.90-3.56
	CH3	1.5- 4.7	114.3	109-130	1.11	0.77- 1.58	4.72	4.22-5.59
Pisco	P1	3.6- 5.8	70.3	40- 99	2.52	1.65- 3.89	1.77	0.57-2.72
	P2	7.0-10.0	28.1	5-162	2.75	0.89-17.91	1.50	0.57-3.18
Tacna (18°S)	T1	5.7- 7.6	16.7	0- 32	5.97	0.50-48.22	0.77	0.42-1.57
Gari solida								
Chimbote	CH1	3.9- 5.0	30.3	4-126	2.78	0.79- 3.20	2.34	0.89-4.75
	CH2	4.4- 6.6	24.0	7- 48	2.05	1.24- 3.09	2.05	0.99-3.91
Callao	C1	5.4- 9.5	66.1	20-140	2.26	0.87- 3.70	2.70	0.41-7.95
Pisco	P2	7.0- 8.5	4.3	0- 21	1.65	0.42- 3.18	0.46	0.01-1.54
Donax asper								
Chimbote	CH1	-	33.4	9-173	-		-	
	CH2	2.1- 3.1	52.9	12-231	2.41	0.89- 4.53	0.54	0.01-1.21

For location of sample sites, see Figure 9

Mud from the same areas has also been analysed for heavy metals (Echegaray et al., 1986). Mercury ranged from 0.17 to 0.71 mg/kg, with high values at Chimbote (0.71 mg/kg), Callao (0.69 mg/kg) and Tacna (0.65 mg/kg). Copper was highest in mud from the mining zones of Callao (134.15 mg/kg) and Tacna (135.83 mg/kg). Cadmium showed values of 5.65 and 6.77 mg/kg at Callao near the mouth of the Rimac River, affected both by mining tailings and by industrial pollution from the Peruvian capital.

Oil pollution monitoring along the Peruvian coast

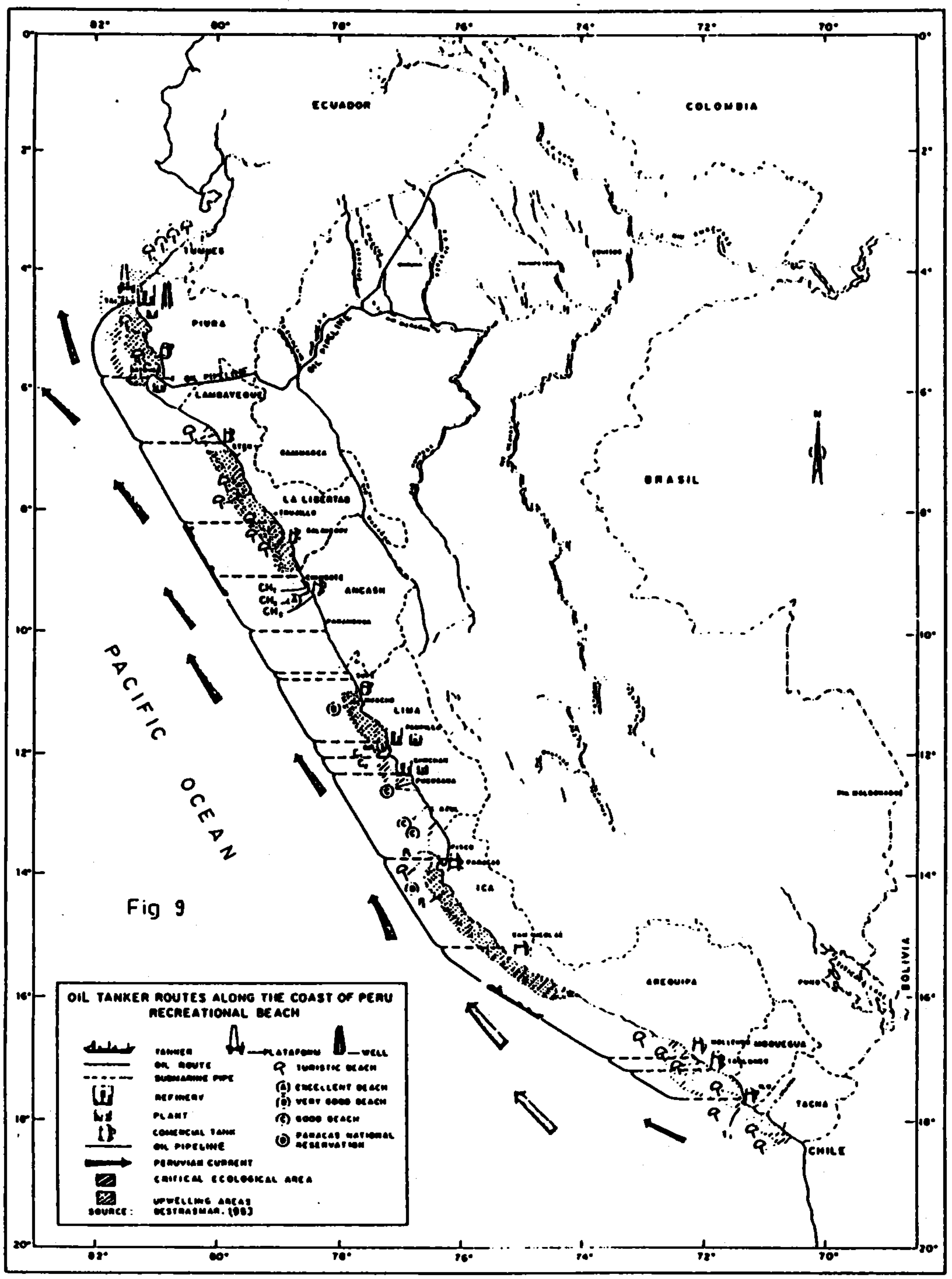
Since the beginning of the 1980's, oil has been Peru's most important source of external revenues. There are three refineries on the coast: Talara in the north with a capacity of 58,000 barrels/day; La Pampilla, capacity 92,000 barrels/day; and Conchan, 6,000 barrels/day (Figure 9), producing a full range of refined petroleum products for internal consumption and export. Both exports and some products for domestic consumption are distributed by sea (Table 7).

Table 7: Shipment of crude oil and other products from Peruvian refineries in 1986 (Thousands of barrels)

Refinery	Coastal trade	Transport to sale plants	Receipt of crude oil/other
Talara	17,631.67	- - -	- - -
La Pampilla	8,186.11	11,461.94 (by pipeline)	34,659.42
Conchan	- - -	2,034.68 (by tank truck)	2,138.37
TOTAL	25,817.78	13,496.62	36,797.79

Source: Petro-Peru, 1987.

Figure 9: Oil shipment routes, recreational beaches and pollution sampling sites along the coast of Peru



Oil produced in the jungle is transported through an 856 km pipeline across the Andes to Bayovar Port on the coast (Figure 9) at a volume of 200,000 barrels/day. Offshore production comes from 85 platforms in four fields at depths varying from 18 to 90 metres. The state company Petro-Peru operates eight product storage depots along the coast; all except Callao are supplied by a small tanker fleet from 10,000 to 25,000 DWT offloading through submarine pipelines from moorings close to the land.

Oil activity risks and accidents

The development of the oil industry and the transport of its products carries the risk of environmental damage due to oil pollution. The risk of spills is higher in harbours and terminals where oil is handled. In Peru, an important part of the internal transport of petroleum products is by sea, as is all of the export of crude oil. Table 8 shows ship movements and the volume transported for one year (1982).

Table 8: Vessel movements in Peruvian ports in 1982
(from ENAPU Annual Report, 1982)

Port	Number of vessels	Gross Registered Tonnage
ENAPU ports		
Talara	460	2,539,634
Paita (large vessels)	233	1,671,788
Paita (small vessels)	156	9,360
Eten	48	709,816
Pacasmayo	11	73,582
Chicama	4	39,796
Salaverry	108	1,249,908
Chimbote	228	2,176,353
Supe	48	563,467
Chancay	22	3,607
Callao	1,760	14,672,035
General San Martin	150	1,472,323
Matarani	348	3,290,568
Ilo	65	992,410
Iquitos (large vessels)	36	200,809
Iquitos (small vessels)	1,927	115,620
Pucallpa (small vessels)	682	- - -
Other ports		
Negritos	14	331,237
Bayovar	86	4,049,266
San Nicolas	64	3,657,162
Ilo Southern	175	1,620,049
TOTAL	6,625	39,438,790

Peruvian refineries take considerable precautions to prevent oil spills. Talara, in the north-west of Peru, with a production of 3,067,730 barrels/year, has two submarine pipelines 2045 m long, and a land reception facility for ballast and polluted tanker water of 10,000 barrels capacity. The La Pampilla refinery north-west of Callao produces 4,574,700 barrels/year. Its submarine pipelines include one 85 cm in diameter and two 40 cm in diameter from 3 to 7 km long, and its land reception facility consists of a pool for ballast capable of holding 6,300 cubic metres or over 50,000 barrels. At Conchan south of Callao, producing 661,500 barrels/year, there are two pipelines of 45 cm and 25 cm diameter about 1 km long. Conchan has no land reception facilities. The Bayovar loading port for shipment of crude oil from the jungle pipeline has a reception facility holding 90,000 barrels. The submarine pipelines are protected from corrosion by cathodes which are changed periodically.

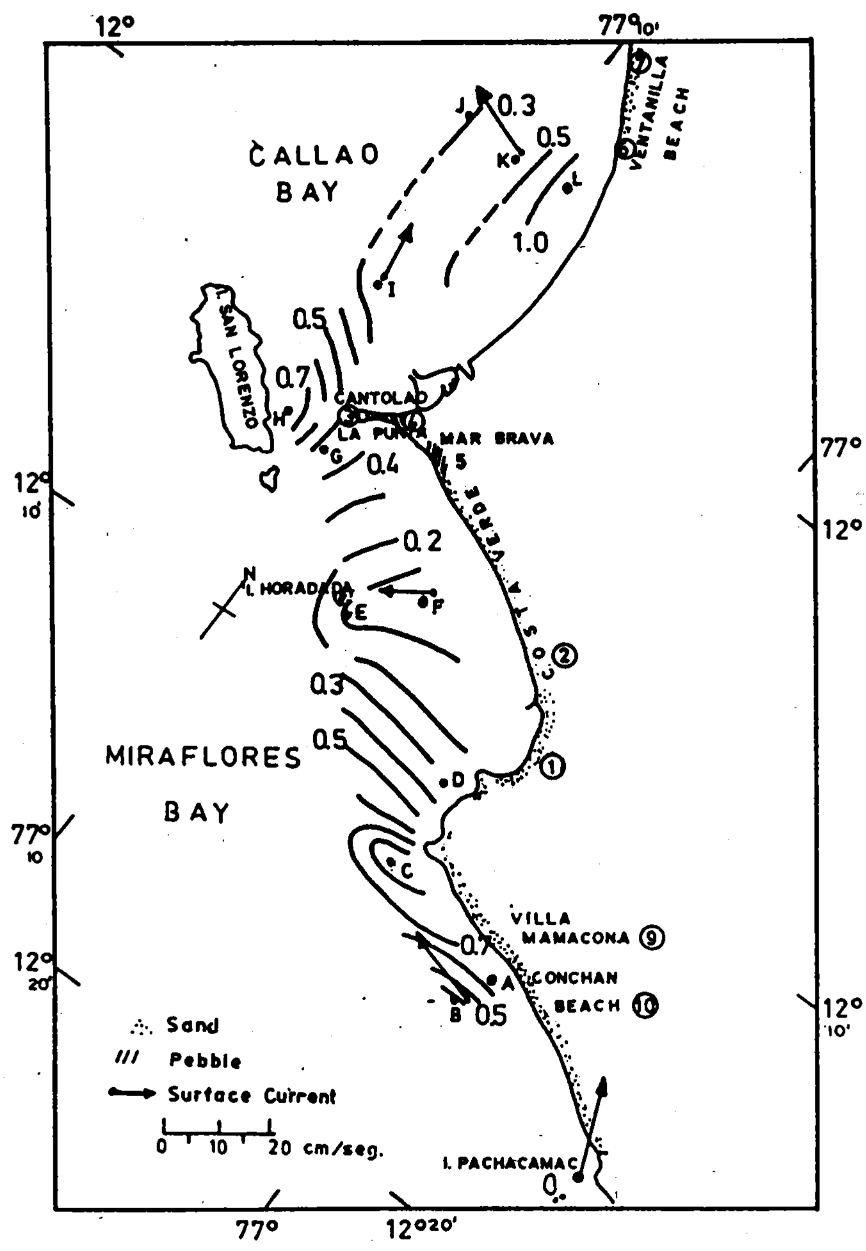
Some spills have occurred, however. About 9 years ago, the submarine pipeline broke at Talara, spilling 2,500 barrels, and the crude reached some beaches in the Cabo Blanco area. The biggest and most recent spill was at Conchan in August, 1984, when 16,800 barrels of jungle crude oil (26° API) were spread on the beaches. Even 18 days later, the surface of

Miraflores Bay had oil patches of 100 to 1000 square metres, affecting the activity of small fishes. Benthic organisms such as bivalve molluscs, crabs and sea urchins collected 24 km from the site of the spill but still within the affected area had traces of oil from 0.10 to 0.20 µg/g. The sandy beaches of Conchan had high concentrations of tar balls reaching 6 cm deep as well as oil slicks and dead animals such as seabirds, crabs and bivalve molluscs.

Marine oil pollution at Callao

A 1981 study sponsored by the CPPS determined the areas of Peru most exposed to oil pollution: Talara, Bayovar and Callao. Subsequently, as part of the UNEP/CPPS Action Plan activities on research, monitoring and control of marine pollution by petroleum hydrocarbons, Peru began studies in the Callao area, from 11°55' to 12°17'S. Sea water samples were taken from the beaches and up to 4 miles offshore (Figure 10).

Figure 10: Dissolved hydrocarbons in Callao and Miraflores Bays (µg/l)
(from Jacinto and Moron, 1987)



The analyses in Table 9 show that the highest concentrations of dissolved hydrocarbons were offshore near the refineries at Pampilla (1.47 µg/l), Conchan (0.62 µg/l) and north of Conchan (0.85 µg/l). Of the sea water samples taken from the beaches, the highest value was 3.37 µg/l at La Punta, possibly due to the presence of chlorophyll in the area which may have influenced the flourescence of the sample during analysis (Jacinto and Moron, 1987).

The observations of tar balls correspond to areas close to the Pampilla and Conchon refineries, where small occasional oil spills are routine.

Table 9: Dissolved hydrocarbons in sea water and tarball occurrence in the Callao area June 1986 (from Jacinto and Moron, 1987)

Station	Offshore Hydrocarbons (µg/l)	Station	Seashore Hydrocarbons (µg/l)	Tarballs on sand (g/m^2)
A	0.62			
B	0.36	1	0.07	-
C	0.85	2	0.09	-
D	0.27	3	3.37	-
E	0.05	4	-	-
F	0.06	5	-	-
G	0.41	6	0.17	0.181
H	0.74	7	0.42	0.078
I	0.25	8	0.28	-
J	0.30	9	0.13	0.017
K	0.24			
L	1.47			

For station locations, see Figure 10

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SURVEY AND MONITORING OF MARINE POLLUTION IN THE BAY OF PANAMA

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ABSTRACT

As a result of the co-ordinated programme of marine pollution research and monitoring in the South-East Pacific (CONPACSE), the characterization and monitoring of pollution in the Bay of Panama has been greatly intensified since 1984. Domestic wastes entering the sea from Panama City are estimated at 34 million tons/year and produce 10,914 tons of BOD/year. Sewage is discharged directly into the bay through approximately 20 outfalls, and indirectly via the Matasnillo, Matias Hernandez and Juan Diaz Rivers. In some areas of the bay near the outfalls, coliform counts up to 160,000 MPN/100ml have been found. In spite of the magnitude of these discharges, recent analyses of some heavy metals in bay sediments did not show abnormal accumulations. However, analyses of pesticides in sediments indicated some accumulation of Eldrin and Lindane. Oil pollution is mainly confined to the Port of Balboa at the Pacific entrance of the Panama Canal, with dissolved petroleum hydrocarbons averaging 23 µg/l and reaching a maximum of 70 µg/l.

Introduction

Environmental degradation generally accompanies urban, agricultural and industrial development in many Latin American countries. In the Republic of Panama, the main causes of environmental degradation are slash and burn agriculture, which has reduced the surface area of natural forests; inappropriate management and disposal of domestic and industrial wastes, leading mainly to land and water pollution; and weak enforcement of laws protecting the environment.

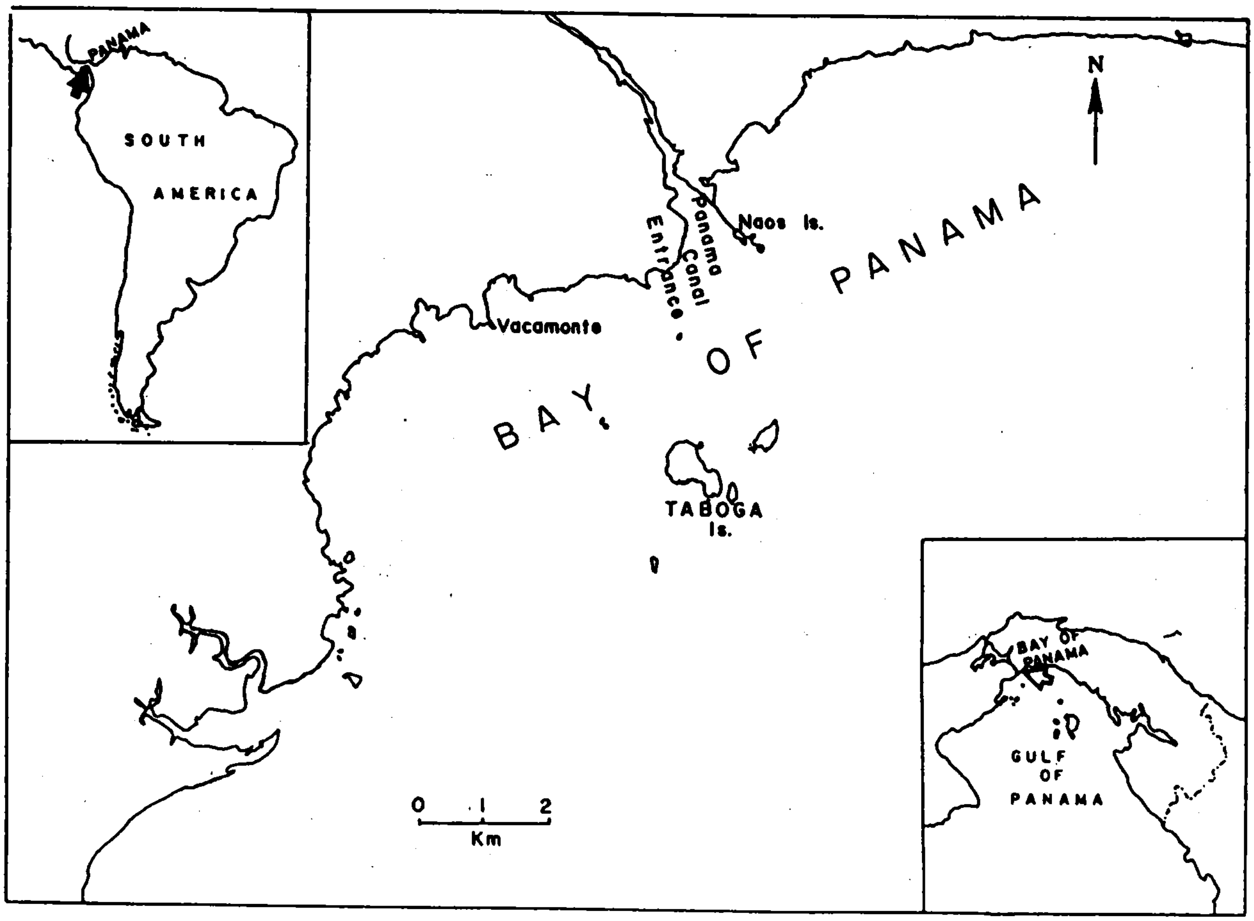
Panama City, on the Pacific Coast, is the major urban centre of the country. Many of its nearly 700,000 inhabitants make their living from local and international commerce, the operation of the Panama Canal, light industries and governmental services. The city is located in the northern part of the Bay of Panama, and most of the industrial and urban wastes are disposed of directly into the Bay without any treatment. In addition, the heavy ship traffic through the Panama Canal and related port activities are another source of marine pollution.

This paper focusses on pollution in the Bay of Panama, presenting levels and dispersion of pollutants as well as projections of future trends. The most recent information in this paper has been gathered through participation by Panama in the CONPACSE research programme of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific, funded by the Regional Seas Programme of the United Nations Environment Programme (UNEP).

Environmental conditions in the Bay of Panama

The Bay of Panama lies within the zone of low atmospheric pressure known as the Equatorial Low Pressure Trough (Figure 1). It is affected by the Intertropical Convergence Zone (ITCZ) formed by the trade winds which converge from each hemisphere. A broad band of weak variable winds, cumuliform cloud masses and frequent and intense rainfall are generally associated with the ITCZ (Forsbergh, 1969). As a consequence, the pattern of rainfall in the Bay of Panama is related to the position of the ITCZ as influenced by wind direction and intensity. Generally, the ITCZ covers the Isthmus of Panama from May to December producing the rainy season. From January to April, the northerly wind forces the ITCZ southward leading to the dry season. The mean annual rainfall along the coast of the Bay of Panama (measured near Panama City) is 1,789 mm, according to the 70 years of records from the Panama Canal Company. Less than 5% of the total annual rainfall is recorded from January to March.

Figure 1: Location of the Bay of Panama

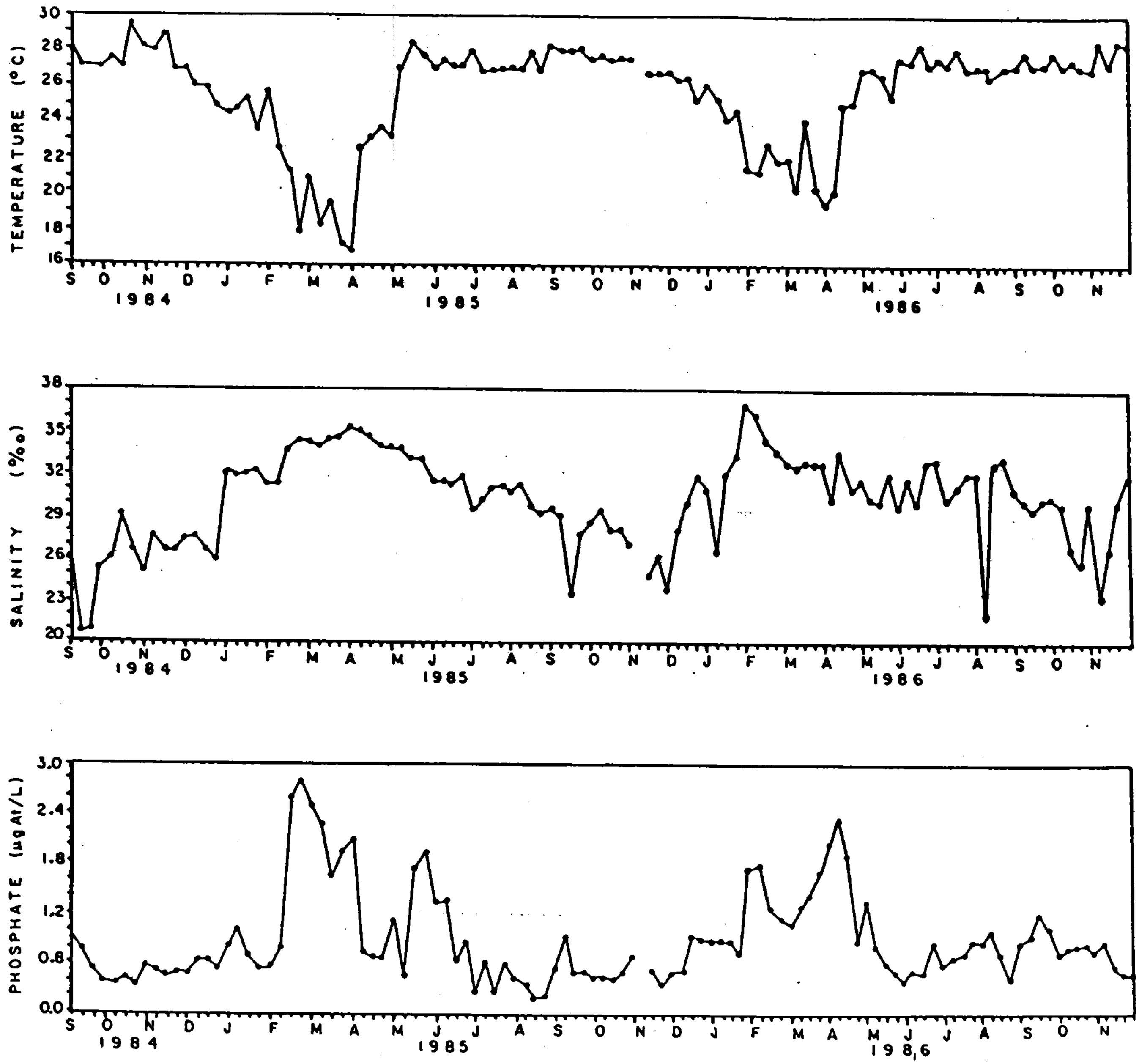


The surface water circulation in the Bay of Panama follows a counterclockwise eddy (Smayda, 1966). According to Bennett (1965), the counterclockwise current system of the Bay is part of the Colombia Current, and follows the isobaths, with maximum current speed (1.5 knots) occurring during the spring tides.

The Bay is under the influence of semi-diurnal tides, with a tidal range at the Panama Canal Pacific entrance at Balboa of nearly 5 metres.

The Bay of Panama is affected by a coastal upwelling induced by the offshore displacement of surface water by northerly winds during the dry season. This produces a decrease in the surface seawater temperature down to 18°C from 28°C during the rainy season. The upwelled water enriches the nutrient level in the euphotic zone, leading to high phytoplankton productivity and the consequent enhancement of the trophic structure (Smayda, 1966; Forsbergh, 1966, 1969; Kwiecinski et al., 1975; Kwiecinski and Chial, 1983). Figure 2 presents weekly records of temperature, salinity, and phosphate from Naos Island in the Bay of Panama. Upwelling may be the most important natural disturbance of marine communities in the Bay, and it has a significant impact on the biology of marine species. The relationship between upwelling and biota has been discussed in relation to phytoplankton studies (Smayda, 1963, 1965, 1966), shrimp and anchovy fisheries in the Gulf of Panama (Kwiecinski, 1978; Forsbergh, 1969; Bayliff, 1963, 1966), the life history of anchovies (Simpson, 1959) and the growth of scleractinian corals in the Pearl Islands (Glynn, 1977).

Figure 2: Surface seawater temperature, salinity and phosphate concentration Naos Island, Bay of Panama, September 1984 to November 1986

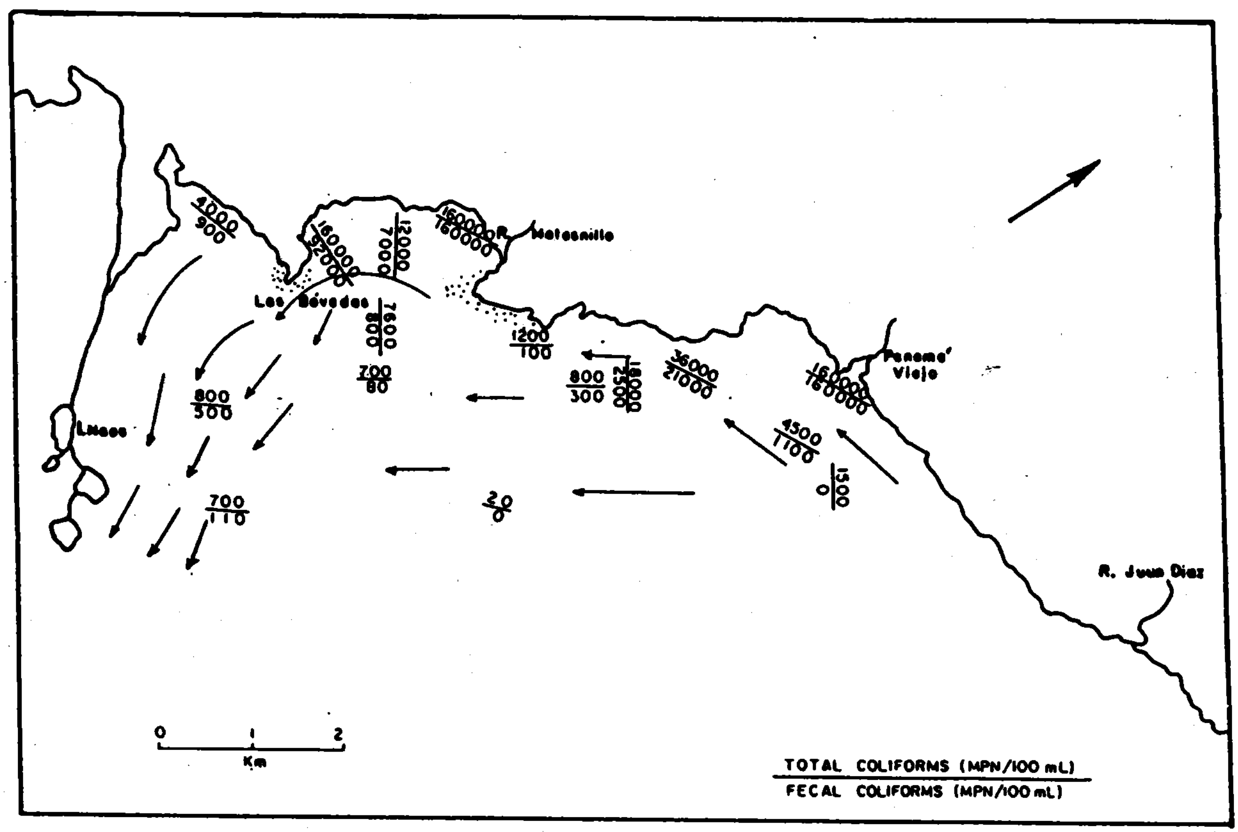


As for man-induced alterations, sewage pollution appears to be the greatest anthropogenic disturbance in the Bay. Panama City each year dumps 34,000,000 metric tons of domestic wastes into the Bay of Panama. This pollution has led to low levels of dissolved oxygen in some parts of the Bay, and to a drastic reduction in the diversity of marine fauna.

Domestic pollution in the Bay of Panama

The Bay of Panama is the most critical example of domestic pollution in Panama. Untreated waste waters are disposed of directly into the sea through about 20 sewage outfalls and 3 small rivers (Matasnillo, Matias Hernandez and Juan Diaz). Recent estimates indicate that sewage from the city generates a BOD_5 of 10,914 metric tons/year (Kwiecinski, 1981). CONPACSE studies (CONAMA, 1986) indicate that over 93% of the BOD load from the Pacific coast of Panama comes from Panama City. As a consequence, coliform counts are high in some parts of the Bay, with faecal coliform counts reaching up to 160,000 MPN/100 ml. These high values decrease to near 100 MPN of faecal coliforms/100 ml toward the western end of the Bay as pollution in diluted by the tides and coastal currents (Figure 3).

Figure 3: Distribution of total and faecal coliforms in the Bay of Panama (after Kwiecinski, 1981)



High concentrations of nitrogen and phosphorus are reported near the coastline of the city in contrast to data collected 5 km offshore (Figure 4). This is another symptom of the eutrophication of the Bay. In addition, two permanent zones of low oxygen concentration have been detected near the Public Market and at the sea front of the old garbage dump which closed in May, 1985 (Figure 5).

At present, Panama City produces 271,973 metric tons of solid wastes per year (744 metric tons/day). Litter generation per capita has been reported near 1.0 kg/day. Until 1985, all these wastes were dumped in the above mentioned garbage dump, located in a mangrove area adjacent to the Bay of Panama. Presently, a sanitary landfill much further inland has replaced the old dump.

Figure 4: Distribution of total nitrogen in the Bay of Panama (8-9 November 1985)

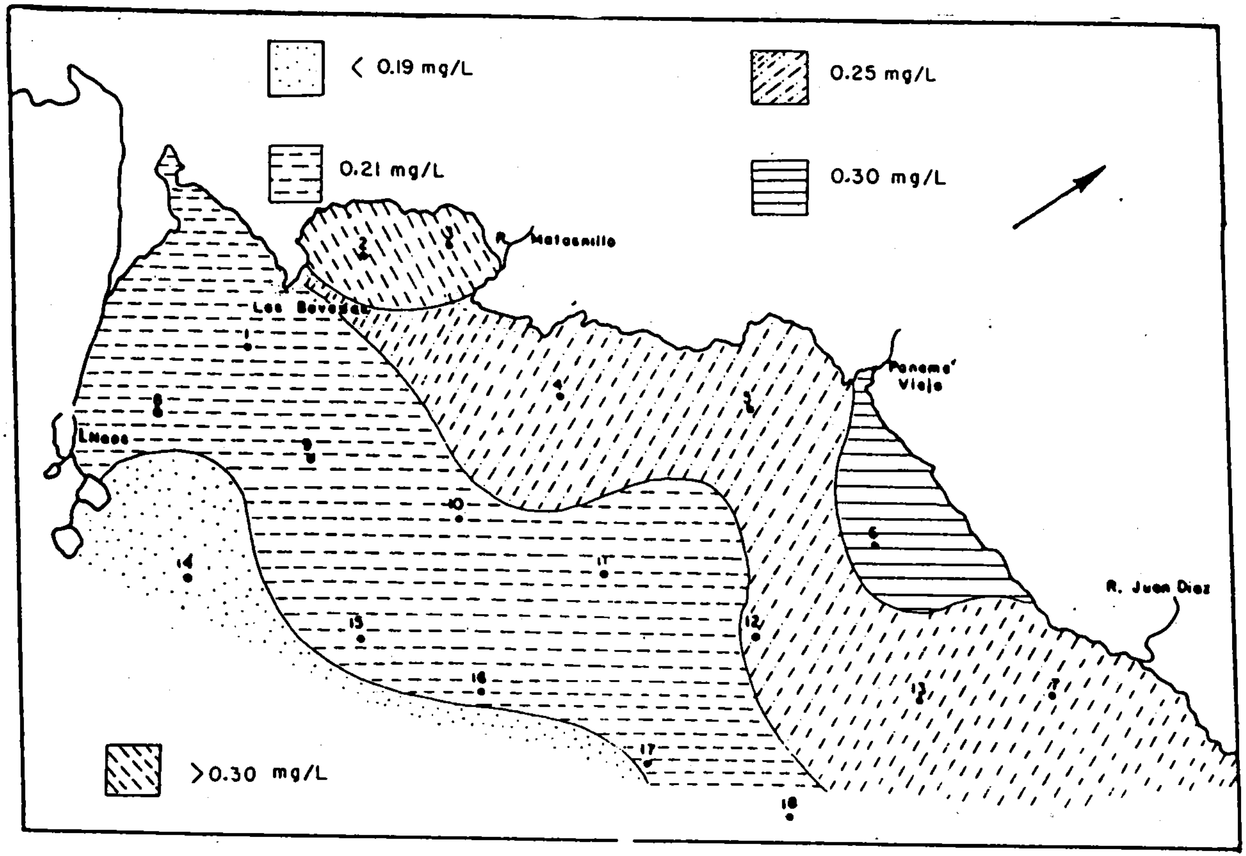
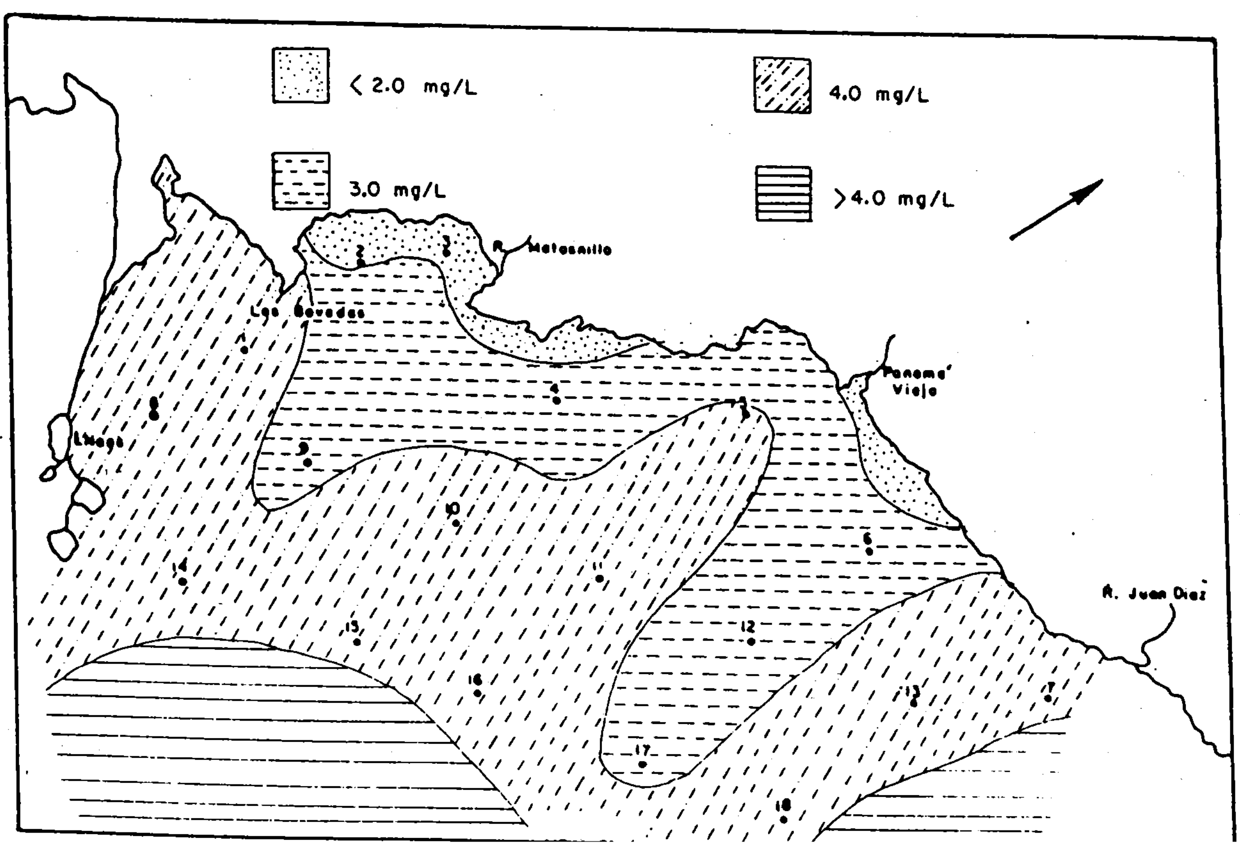


Figure 5: Distribution of dissolved oxygen in the Bay of Panama (8-9 November 1985)



Some projections of the domestic pollution of the Bay of Panama can be inferred from the information gathered from Panamanian public agencies (Table 1). The population of the city is expected to reach approximately 1,164,807 inhabitants by the end of this century. This will imply a doubling of the disposal of litter and sewage; the consumption of drinking water will also nearly double the current demand (Heckadon, 1985; CONAMA, 1986). These figures were used to project the water quality of the Juan Diaz River, one of the natural waterways receiving sewage that ultimately enters the Bay (D'Croz and Kwiecinski, 1980). Table 2 shows the load of sewage pollution as assessed for 1977, and as estimated for the early 21st century. At present, nearly 19,000 cubic metres/day are discharged into the Juan Diaz River, and it is estimated that by the end of this century this figure will increase ten times. The river has a mean discharge rate of 64,000 cu.m/day during the dry season and 473,000 cu.m/day during the rainy season. According to the projection, sewage discharge will be three times greater than normal river volume during the dry season; it will equal at least half the mean river volume during the rainy season.

Table 1: Projected solid waste and sewage production from Panama City, 1985 to 2000

Year	Population	Consumption of drinking water (cu.m/d)	Sewage (cu.m/d)	Solid wastes (metric tons)
1985	750,000	397,000	278,000	750
1990	848,000	500,000	400,000	850
2000	1,033,000	719,000	575,000	1,050

Table 2: Water quality in the Juan Diaz River, 1977 and 2020 (D'Croz and Kwiecinski, 1980)

	1977		2020	
Pollutant	Kg/day	Concentration mg/l	Kg/day	Concentration mg/l
BOD	1700	25.0	40000	588
Suspended solids	2300	34.0	31000	455
Total nitrogen	850	12.0	10000	147
Total phosphorus	150	2.5	2300	34

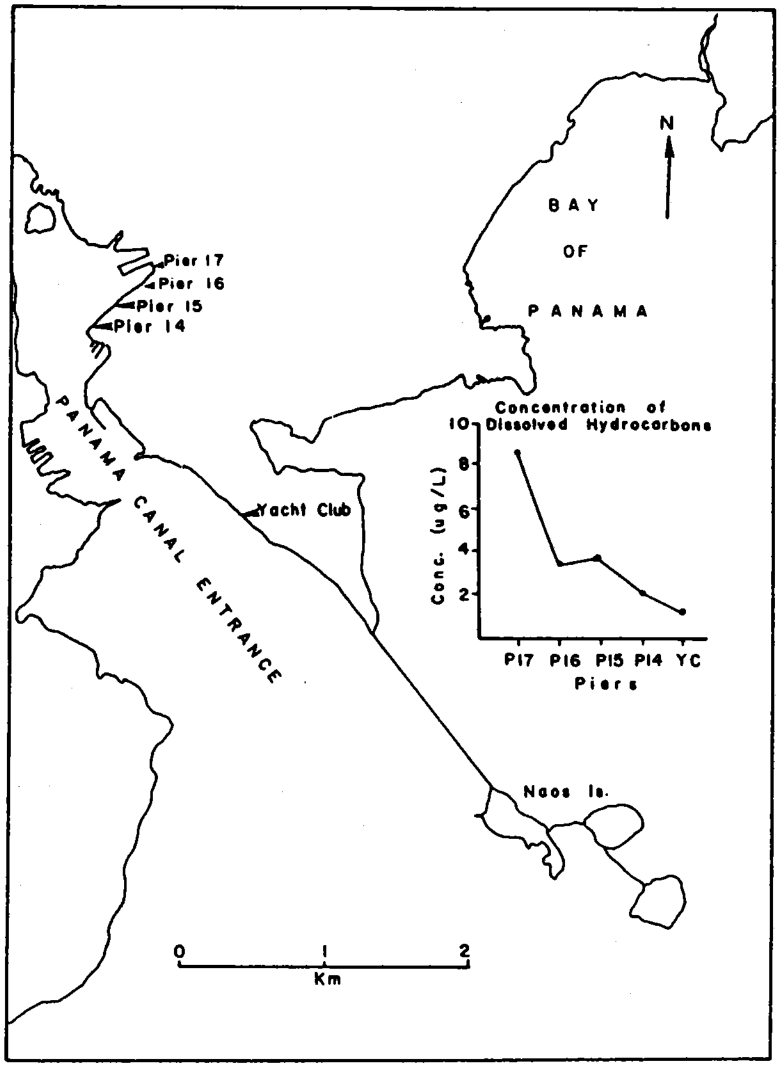
According to the current trends in population growth and sewage discharge from Panama City, nearly 30,000 metric tons/year of BOD are projected for the Bay of Panama by the end of the century, based on a suggested 25 kg of BOD per capita/year (CPPS, 1981).

Marine oil pollution

Around 70 million tons/year of oil are transported across the Isthmus of Panama (CONAMA, 1987a). Records from 1973 to 1984 indicate that an average of 2.5 million tons/year of oil are handled in the Pacific terminal of the Panama Canal for the refueling of approximately 1,900 ships/year. The average oil spilled from these operations is 200 tons/year with a rate of occurrence of 1.6 spills per year.

Oil pollution in the Bay of Panama is confined mostly to the entrance of the Panama Canal. The highest concentration of dissolved hydrocarbons was recorded in the Port of Balboa at the Pacific terminal of the Panama Canal, with an average of 23 µg/l and maximums of 70 µg/l. The area of the Bay adjacent to the Canal entrance has a mean concentration of dissolved hydrocarbons of 2.8 µg/l and a maximum of 10 µg/l, while the concentration in the Pacific side of the canal is generally above 10 µg/l and occasionally exceeds 20 µg/l. Both CONAMA (1987a) and Chial and Sanchez (1985) suggest a gradient of oil pollution originating largely in the Port of Balboa and decreasing seaward (Figure 6).

Figure 6: Concentration of dissolved petroleum hydrocarbons at the Pacific entrance of the Panama Canal (after CONOMA, 1987a)



Pesticides and heavy metals

Panama imports relatively small amounts of insecticides and herbicides. In 1984, imports of pesticides reached approximately 7,000 metric tons (Espinosa, 1985). However, during the past 25 years imports have increased at an annual rate of nearly 5%. According to Espinosa (1985), annual imports of pesticides will exceed 10,000 metric tons by the end of this century. Ninety percent of the pesticides are used in agriculture; the rest is for domestic use. Analyses of seawater from the Bay of Panama showed no traces of pesticides (Gonzalez et al., 1973; CONAMA, 1987b). However, recent analyses of sediments from the Bay of Panama showed some small accumulations. Endrin was recorded in sediments with concentrations up to 0.16 µg/g whereas Lindane and B-BHC were detected below 0.09 µg/g.

There is no evidence of heavy metal pollution in the Bay of Panama (CONAMA, 1986, 1987b). This is not unusual since Panama does not have much heavy industry. Concentrations of heavy metals in seawater have been recorded ranging from 4 to 38 µg/l for copper, 9 to 44 µg/l for zinc, and below 1 µg/l for mercury and cadmium. Recent analyses of marine species from the Bay did not show abnormal accumulations. The mean concentration of these metals in the muscles of 18 species of fishes were as follows: 0.79 ppm for copper, less than 0.03 ppm for cadmium, and 0.1 ppm for mercury.

Development of coastal areas and alteration of hydrological cycles

Panama has 5,000 km^2 of mangrove forests, most of which are on the Pacific coast. Urban and industrial development, as well as land demand for agriculture, have traditionally threatened these mangrove swamps. More recently, the building of ponds for shrimp mariculture has been identified as an important process which might produce changes in the coastal zone. Recent studies suggest that the surface of mangrove swamps on the western side of the Gulf of Panama has decreased an average of 1% annually from 1965 to 1982. Aerial photographs show that most of the changes occurred after 1979.

Two large rivers on the Pacific side of Panama have been dammed for hydroelectric purposes. The Bayano River, which drains into the Bay of Panama, has a hydroelectric plant that generates 150 MW. The damming of the Bayano River created a highly eutrophic reservoir of 365 km^2 in the lower part of the watershed with a maximum storage volume of 5,000 x 10^6 m^3. Among the expected consequences of the damming of this river on the ecology of the Bay of Panama are a decrease in downstream water quality, an impact on the reproduction and migratory patterns of some aquatic species, and increased tidal intrusion of seawater into the riverine habitat.

Conclusion

The pollution in the Bay of Panama is mostly generated by untreated urban and light industrial wastes disposed of directly or indirectly into the sea. This pollution has led to relatively high concentrations of nitrogen and phosphorus along the coast, and depleted concentrations of dissolved oxygen in some critical areas of the Bay. In addition, some moderate oil pollution has been detected as a consequence of the port activities at the Pacific terminal of the Panama Canal.

The most recent characterization of this pollution has been achieved through the participation of Panama in the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific, a regional co-operative programme sponsored by UNEp and co-ordinated by the Permanent Commission for the South Pacific (CPPS).

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific which facilitated the presentation of this paper at the UNEP Symposium on Regional Co-operation on Environmental Protection at the XVI Pacific Science Congress. Dr. Jorge Illueca, Executive Secretary of the Comision Nacional del Medioambiente, Republic of Panama, reviewed the manuscript and provided valuable comments. Mr. Juan Del Rosario and José Gil Lasso provided important help in the preparation of the figures.

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SURVEY AND MONITORING OF MARINE POLLUTION IN CHILE

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ABSTRACT

Research activities in Chile under CONPACSE began in 1985. The Institute of Oceanology of the University of Valparaiso is carrying out research and monitoring of pollution by petroleum hydrocarbons and their effects on marine communities, while the University of Concepcion is monitoring marine pollution in Concepcion. In Valparaiso, information was collected from the literature and from baseline studies on bathimetry, sediments, water masses, circulation, physical and chemical parameters of seawater, phytoplankton, soft and hard bottom communities, and visual observations of floating pollutants from a fixed coastal platform. Data was also collected on petroleum hydrocarbons dispersed/dissolved in seawater, and in sediments and organisms, as well as tar ball occurrence on beaches, and other complementary measurements such as air temperature, winds and waves. Studies in the Concepcion area during 1979 on hydrography, marine biology and some pollutant levels have provided background information for planning the CONPACSE research programme. Since 1985, environmental research has concentrated on oceanographic data and on the determination of selected pollutants such as Hg, Cd, Lindane, DDT, DDE, Aldrin and coliforms in water, sediments and marine organisms. This paper reviews the results of these programmes, as well as other information concerning future activities in environmental monitoring and management.

Introduction

The Permanent Commission for the South Pacific (CPPS) with support from FAO made the first marine pollution survey in the South-East Pacific Ocean (Arriaga, 1976). The data were primarily based on estimates of populations with sewer services, industrial effluents, dumped or spilled oil, the risk of oil pollution from oil pipeline terminals and refineries, etc. Nevertheless, some critical areas like Valparaiso and Concepcion were identified along the Chilean coast. Later work has increased the data available (Cabrera, 1979; Castilla, 1981; Gallardo, 1984; Boré et al., 1986).

Information about hydrocarbons, metals, pesticides and other pollutants in seawater, organisms and sediments was limited before 1981 when the CPPS, with UNEP co-operation, launched the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific. Systematic research activities in Chile began in 1985 with two projects: "Research and monitoring of pollution by petroleum hydrocarbons and their effects on marine communities in Valparaiso" at the University of Valparaiso, and "Monitoring of marine pollution in Concepcion" at the University of Concepcion. Both are part of the CONPACSE (Contaminacion Pacifico Sudeste) programme.

The information in this paper has been gathered mostly from reports to the regional co-ordinating unit at CPPS (Instituto de Oceanologia, Universidad de Valparaiso, 1985, 1986; Universidad de Concepcion, 1985, 1986a) as well as from other publications related to ongoing research.

Overview of Chile

Continental Chile (excluding the Antarctic claims and the oceanic islands) is located along the south-eastern boundary of the Pacific Ocean between 18° and 56° S, with a coastline 4,200 km long. The country averages 117 km in width (maximum 380 km, minimum 90 km), with a surface area of 756,626 sq. km. The coastline is fairly even from the northern boundary to 42° S; further south it becomes uneven, with many islands, fjords and canals.

The climate is very diverse. Deserts dominate the northern territory from 18° to 32° S, with very little annual precipitation. There are some winter rains starting at 30° S and increasing considerably from 32° S to a maximum of 5000 mm in the southern region. Mean air temperatures are 18°C in the north and 11°C in the south, descending to 5-6°C in the extreme south (56° S). The first important river basin, the Aconcagua River, is at 33° S, reaching the coast at Valparaiso Bay. The climate from there to the Bio Bio River near Concepcion at 37° S is Mediterranean, with winter rains, and thus stream runoff, increasing from north to south. South of the Bio Bio River, the rains become more regular and the dry season disappears, producing a cold, humid wooded zone. The arid area of the northern desertic zone represents 38% of Chilean territory; the percentage of arid zones rises to over 60% if the elevated cordillera zones, austral ice caps, etc. are included (Börgel, 1983).

The Chilean population at the last census in 1982 was 11,275,440, with an annual growth rate of 1.7%. Three quarters of the population live along the 500 km of coast between Valparaiso (33° S) and Concepcion (37° S), equivalent to 15.3% of the continental area. Metropolitan Santiago, with 38% of the population, has the highest population density (276 inhabitants per sq. km). Adding the immediate coastal area (Valparaiso) and an area immediately to the south, 54% of the total population occupies 48,000 sq. km or 6% of the Chilean territory, mainly concentrated between the Aconcagua, Maipo and Rapel river basins (Vio, 1983). 81% of all Chileans live in urban areas.

The highest gross national product is in the metropolitan region of Santiago, representing 41.2% of the national GNP. It is followed in importance by Valparaiso (12.2%) and Concepcion (10.9%). Thus the Aconcagua, Maipo and Bio Bio river basins concentrate 64.3% of Chilean GNP (Vio, 1983). These basins represent only 9% of the national territory, but 22% of the road network, and thus the greatest quantities of traffic and motor vehicles. Likewise, Valparaiso and Concepcion receive 20% of the merchandise moving through all Chilean ports (Vio, 1983).

The fishing industry predominates in the Arica-Iquique region (18°30'-20°30' S); the mineral industries, tanneries, food industries and non-metallic minerals are dominant in the Metropolitan Region of Santiago and Valparaiso (33°-34° S); the lumber industry, paper factories and chemical sub-products predominate in the region of Concepcion (36°30 S), together with a fishing industry that ranks second place in production and catch in the country (992,545 tons in 1985).

The urban population of Chile connected to sewage systems has increased from 36% in 1970 to 74% in 1984 (Boré et al., 1986; Sandoval et al., 1985). The percentage of the rural population served by septic tanks also increased from 12% in 1970 to 27% in 1982 (Sandoval et al., 1985). However, 95% of the water-borne wastes directly or indirectly reach the ocean without any type of treatment (Boré et al., 1986).

The sewage discharged directly into the oceans comes from 1,343,000 inhabitants in the coastal regions, giving an estimated water discharge of 3,315 l/sec; 26,456 tons BOD/year; 537 tons P/year; 4,432 tons N/year and 26,859 tons suspended solids/year. In addition, the indirect discharge through the river basins comes from 5,771,000 inhabitants, for which the estimated water discharge rate is 19,195 l/sec; 113,679 tons BOD/year; 2,308 tons P/year; 19,043 tons N/year and 115,410 tons suspended solids/year. The total estimate of BOD for Chile, reaching the ocean directly or indirectly, is 140,135 tons/year (Boré et al., 1986).

VALPARAÍSO REGION

General information

The Valparaiso region has a straight shoreline of approximately 200 km. It is bordered on the east by Santiago, the capital of Chile. Three important river basins flow into the

Pacific along about 80 km of the shoreline. These basins receive the waste water of 4,340,000 inhabitants. The major part of this input comes from the Maipo River, which receives most of the waste water from Santiago. The mouth of this river is 70 km south of Valparaiso Bay.

600,000 people reside in the coastal region of Valparaiso Bay, including Valparaiso, Vina del Mar and other neighboring cities (Figure 1). 83% of the region's total waste water empties directly into the ocean without any treatment (Boré et al., 1986). The Aconcagua River flows into the northern end of Valparaiso Bay, adding to its pollution load (Table 1).

Figure 1: The Valparaiso region

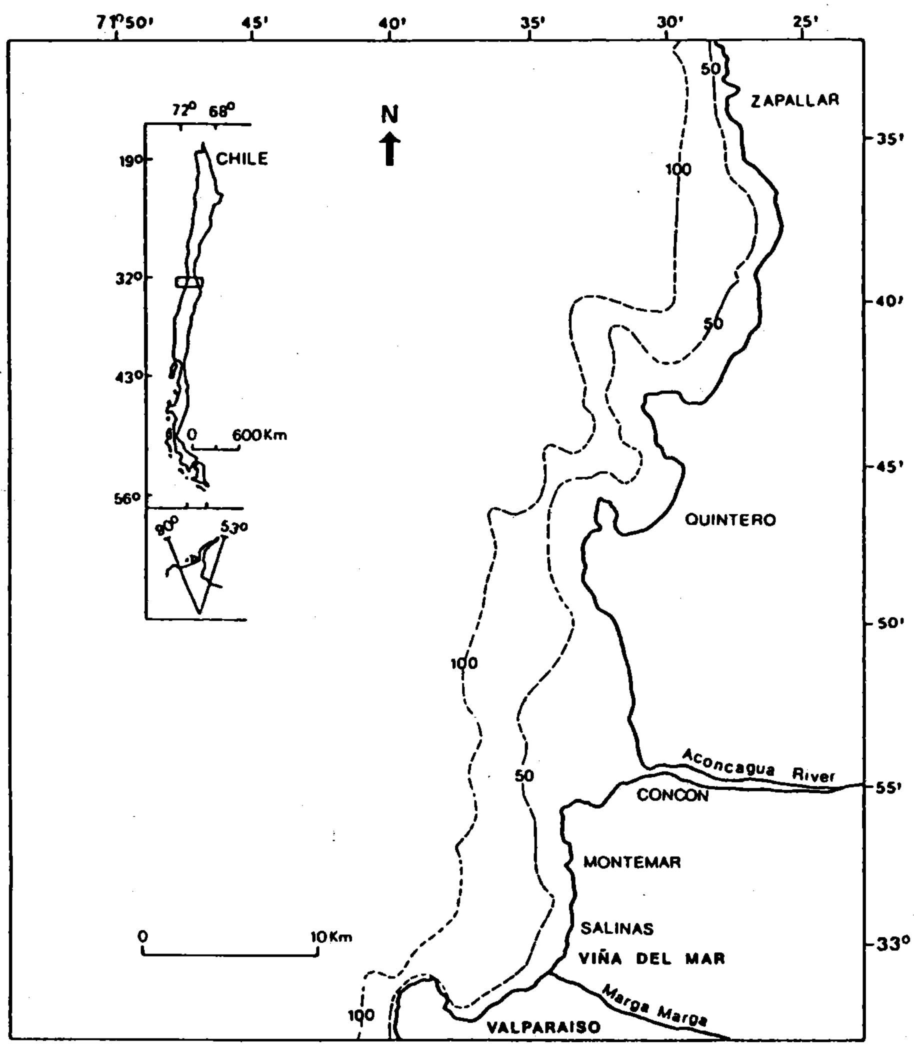


Table 1: Estimated organic load from domestic wastes in Valparaiso Bay and Concepcion (tons/year, based on BOD_5=19.7; P=0.4; N=3.3; SS=20 kg/person/year) (Data from Boré et al., 1986)

	Valparaiso Direct Discharge	Valparaiso Indirect Discharge	Concepcion Direct Discharge	Concepcion Indirect Discharge
BOD	9,754	4,730	3,823	4,293
N	1,633	799	640	719
P	198	96	78	87
Suspended solids	9,902	4,802	3,881	4,359

The coastal region of Valparaiso has the most highly developed tourist industry in the country. Since it is close to the capital (112 km), the area receives approximately 450,000 summer visitors, and the total of summer residents increases by 225,000 (CEPAL et al., 1986). As a result, up to 240,000 E. coli (MPN/100 ml) have been recorded in Valparaiso Bay during the summer of 1982 (CEPAL et al., 1986).

The ports of the Valparaiso region loaded and unloaded over 9 million tons of goods in 1980, amounting to 20% of the national total (Vio, 1983). The two principal industries in the coastal region are the petroleum refinery at Con Con in the extreme north of the bay, and the electrolytic copper refinery in the port of Quintero, 40 km north. Table 2 lists other important industries.

Table 2: Industries discharging into Valparaiso Bay directly or through the Aconcagua River (from Boré et al., 1986)

Industry	Number	Discharge volume (m^3/day)
Copper mine	1	15,000
Oil refinery	1	7,760
Coke gas factory	2	615
Chemicals	5	2,525
Loading and discharging oil	3	
Tanneries	4	339
Fruit preserving	5	10,899
Slaughter houses, cured meat	10	800
Fisheries	1	183
Breweries	3	3,660
Soft drink	2	450
Seaweed industry	1	1,640
Other food	2	103
Textile	1	950
Paper	1	66

The programme of "Research and monitoring of pollution by petroleum hydrocarbons and their effects on marine communities" in the Valparaiso area follows the CONPACSE plan issued by CPPS/UNEP/IOC (1984a). Research began in 1985, and the results to date have been reported by the Instituto de Oceanologia (1985, 1986). Research started with a review of the existing information on the Valparaiso area, as a basis for continuing studies. Areas where information was lacking were especially emphasized. Data on petroleum hydrocarbons in water, sediments and marine organisms were obtained using the CPPS/UNEP analytical protocols (CPPS/UNEP, 1983a, 1983b, 1984; CPPS/UNEP/IOC, 1984a, 1984b).

Bathymetry and sediments of the study area

The study area is situated on the central coast of Chile in Valparaiso province between 32°30' and 33°03' S. The localities of Montemar-Salinas and Con Con in Valparaiso Bay, Quintero Bay and Zapallar Bay were selected for their distinct exposures to different types and quantities of pollution sources (Figure 1). The "Instituto de Oceanologia" is located in Montemar and the surrounding coastal area is fenced off to exclude the public. Con Con is the site of the petroleum refinery and the mouth of the Aconcagua River. A copper refinery, a thermal electric plant and a number of crude oil loading and unloading buoys are located in Quintero. Zapallar is considered to be an unpolluted area, with public waste water effluents only during the summer months (January to March).

The shoreline consists of rocky cliffs with different degrees of exposure to wave action, and scattered sandy beaches. The continental shelf is very narrow, with a drop in the seafloor profile from the tide mark to offshore. Off of Valparaiso, the continental shelf has a slope of 0.5 to 1.6%. The flattest portion is between 100 and 150 m depth. On the continental slope, the seafloor profile increases from 7.5 to 9.6%. The 50 m isobath enters Valparaiso Bay and comes close to the shore. To the north and in front of the Aconcagua River mouth this isobath is found further seaward. Near Quintero this isobath approaches the coast but does not enter Quintero Bay. The small Zapallar Bay is only 30 m deep.

In Valparaiso Bay, most beaches have large sand grains averaging 0.77 mm, producing very permeable beaches. On the continental shelf and the continental slope to 600 m, the bottom sediments are muddy-sands and sandy-muds with a mean particle diameter of 46.4 µm, being 90% of terrestrial origin and 10% biogenic material. The sediments cover 90% of the shelf, with the remaining 10% being uplifted crystalline basement rock (Valenzuela et al., 1979). At three stations between 35 and 55 m depth, organic material averaged between 0.71 and 2.36% (Stuardo et al., 1981). Off the mouth of the Aconcagua River, at a total of 16 stations along three transects at between 20 and 95 m, 56% of the stations showed muddy-sands, and the rest sandy-muds. The quantity of organic material varied between 0.23 and 2.78% (Andrade, 1986a).

Quintero Bay is much smaller, closed and with a more gradual slope than Valparaiso Bay. The deepest depth at its mouth is 50 m. The seafloor sediments are mostly sandy, with grain size ranging between 0.06 and 0.25 mm (Andrade, 1986b).

General properties of the water

Two water masses occur off Valparaiso. The Sub-antarctic Surface Water (0-100 m) is characterized by: surface to sigma 26.34, salinity 33.8-34.4 ‰, oxygen >5 ml/l and temperature 11-18°C. The Equatorial Subsurface Water from 100 m down to 450 m has: sigma 26.34-26.97, salinity 34.4-34.9 ‰, oxygen <1 ml/l and temperature 7-12°C. During the "El Nino", subtropical waters were detected at the surface off Quintero (Instituto de Oceanologia, 1985).

During spring and summer in Valparaiso Bay, solar radiation increases the surface water temperature, creating a thermocline above 30 m depth. This thermocline is frequently broken, however, when SW winds are strong and steady enough to produce intermittent vertical mixing eddies. During autumn and winter, temperatures become more uniform throughout the water column as the surface warming effect disappears.

Table 3 shows the surface physico-chemical seawater characteristics off Valparaiso between the coast and 5 miles offshore, and at a station 50 m deep located 1.5 miles offshore. At the bottom of the bay between the 20 and 200 m isobaths, seawater temperature oscillates between 10 and 14°C. Bottom oxygen concentrations are also below 1 ml/l, except at 5 stations at the extreme north and south, where values were between 1 and 3 ml/l (Ramorino, 1968).

Table 3: Mean properties of seawater in Valparaiso Bay
Surface stations (s) from coast to 9.3 km; 50 m deep station 2.8 km offshore
(from Instituto de Oceanologia, 1985; Pizarro, 1976)

		t °C	S ‰	O_2 ml/l	NO_3-N µmol/l	NO_2-N µmol/l	PO_4-P µmol/l
Summer	s	14.2-16.3	32.4-33.7	5.8-6.8	2.7-4.6	0.17	0.7-1.1
	50m	11.28	34.35	2.09	21.60	--	2.59
Autumn	s	13.5-14.8	34.0-34.2	5.0-6.2	5.8-9.8	0.10-0.23	0.4-1.3
	50m	11.19	34.35	3.01	23.03	--	2.05
Winter	s	12.4-14.0	33.0-34.0	5.6-6.4	11.1-14.3	0.27-0.48	1.0-1.4
	50m	11.15	34.42	2.83	--	--	2.16
Spring	s	13.4-15.5	33.6-34.2	5.7-6.8	3.3-18.9	0.13	0.4-1.3
	50m	10.89	34.57	1.66	26.86	--	2.73

At about 2.8 km off Quintero, mean seawater characteristics are similar to those at Valparaiso. During the "El Nino", however, the values for spring and autumn 1983 were the following: t= 15.3-18.4°C; salinity 33-34 ‰; O_2= 3.18-5.5 ml/l; PO_4-P= 0.9-1.4 µmol/l; NO_3-N= 0.15-9.16 µmol/l; NO_2-N= 0.07-0.3 µmol/l (Instituto de Oceanologia, 1985).

The currents within Valparaiso Bay are shown in Figures 2 and 3, produced by the Instituto Hidrografico de la Armada (1984) using data from the scientific literature. This study also suggests that the deep water currents are very similar to the surface currents.

Figure 2: Surface current patterns in Valparaiso Bay at high tide (from Instituto Hidrografico de la Armada, 1984)

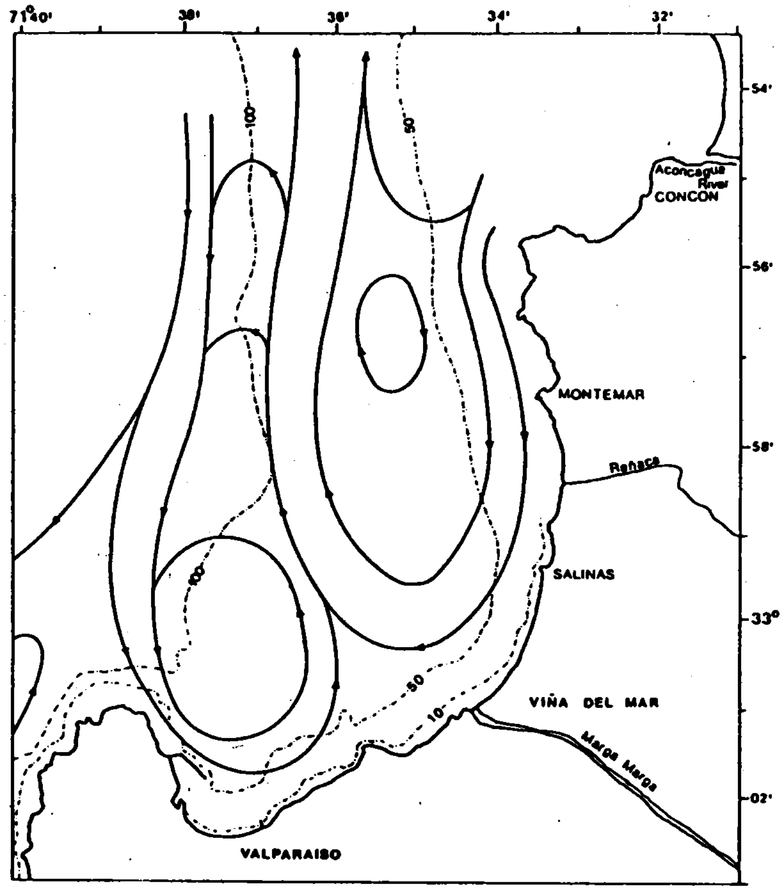
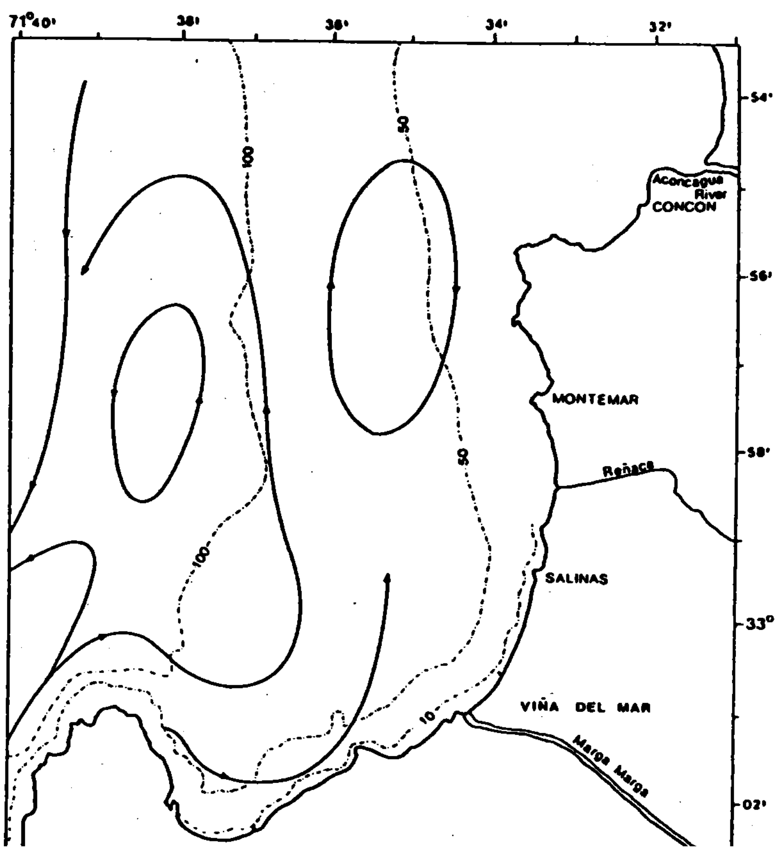


Figure 3: Surface current patterns in Valparaiso Bay at low tide (from Instituto Hidrografico de la Armada, 1984)



Marine communities

Phytoplankton

Studies on marine phytoplankton began in the 1960's (Avaria, 1965, 1975; Alvial and Avaria, 1982; Munoz and Avaria, 1986). A revision of these papers incorporating recent information was included in a CONPACSE report (Instituto de Oceanologia, 1985).

More than 200 species and varieties of diatoms, dinoflagellates and silicoflagellates have been identified in the phytoplankton. The diatoms are largely dominant, with 10% of the diatom species making up the greater part of the phytoplankton biomass. After the diatom proliferations during the summer months in periods of strong vertical stability, the dinoflagellates and silicoflagellates become qualitatively more significant. The species most characteristic by their abundance and permanence in the plankton are: Chaetoceros debilis, C. compressus, C. socialis, Leptocylindrus danicus, Detonula pumila, Skeletonema costatum, Thalassiosira aestivalis, Nitzchia pseudoseriata, Ceratium furca, C. tripos, C. fusus, Protoperidinium conicoides and Dyctiocha speculum.

Most of these species are neritic, cosmopolitan euroic or temperate water cosmopolitan. Cold water species are common, while offshore warm water species are rarely recorded. The species diversity index, calculated from sedimented samples, is low, ranging from 0.1 to 3.3 bit/cell., but most commonly between 1.0 and 2.0 bit/cell. The lowest values are recorded during the biggest spring-summer proliferations. The highest values correspond to the winter months.

Species successions tend to be very short since the Valparaiso area is influenced by an intense coastal upwelling zone located south of Valparaiso Bay. More advanced states of species succession are observed in winter, or in summer on the rare occasions when the water column remains vertically stable for long periods of time. The succession begins with small diatom proliferations, such as Detonula pumila and Skeletonema costatum, followed by large species of the genus Chaetoceros, among others, and species that require less nutrients such as Biddulphia longicruris, before ending with a variety of diatoms such as Rhizosolenia and Bacteriastrum delicatum, and a large number of dinoflagellates.

The phytoplankton biomass, assessed by cell counts, algal weight from volume determinations, and pigment concentrations, is high with large variations over short periods and comparatively large annual variations. The lowest values (<1.5 cell/ml, 0.1 mg/l and 0.6 mg/l chlorophyll "a"/m^3) occur in May, and the highest values (>1,250 cell/ml, 6.7 mg/l and 4.3 mg/l chlorophyll "a"/m^3) in December. The biomass increases gradually from June to September, rises suddenly from October to December, and remains high until April. Eleven species of small diatoms constitute 75% of the annual biomass. Some big species, such as the diatoms Eucarpia cornuta and Lauderia annulata and the dinoflagellates Ceratium tripos and C. furca are of no quantitative importance annually, but can have considerable influence on the biomass for short periods of time.

The strong turbulence of the Valparaiso area makes it difficult to establish a vertical distribution pattern. The highest cell densities are generally observed at between 5 and 10 metres. The horizontal distribution is similar in all the areas studied, except for the coastal stations in front of the Aconcagua River where continental water species are present and the pigment biomass is highly variable.

The greatest phytoplankton activity is during the seven months from October to the end of April, coinciding with the greatest frequency of upwelling. The period of lowest activity is between the end of April and October. Even during the richest period, strong oscillations in the biomass occur over short periods of time because the pycnocline formed by the intense solar radiation is frequently altered by the south-southwest winds.

In the Valparaiso area, non-periodic red tide phenomena may be caused by Mesodinium rubrum, Prorocentrum micans, Scrippsiella trochoidea and Prorocentrum gracile. These red tides appear in late summer and early autumn, associated with abnormally high temperatures for the time of year, intense solar radiation and frequent calm periods of diminishing S-SW winds, which contribute to the high stability of the water column. The phenomenon is associated with a noticeable reduction in the diatom populations.

Soft bottom communities

Ramorino (1968) studied the bivalve molluscs in Valparaiso Bay at 72 stations ranging from 20 to 200 m depth. He correlated sediment types and depths with species distribution. Out of 22 species, the most frequent were Linnucula pisum and Nuculana cuneata, which were present at 80% of the stations. The species with the highest densities were Cyamiomactra chilensis (1373/m^2) in sandy sediments and L. pisum (1867/m^2) in sandy-mud sediments.

Andrade and Baez (1978) reported information on sublittoral gastropods trawled from muddy-sand bottoms between 25 and 50 m depth in a coastal area within Valparaiso Bay. Out of 10 species, Nassarius dentifer and N. gayi were the most abundant, accounting for 35% and 25% of the total number of gastropods. Stuardo et al. (1979) found average monthly densities of 1178, 1009, and 398 individuals/m^2, and average biomass values of 97, 107 and 64 g/m^2 (wet weight) at three stations in Valparaiso Bay on muddy and muddy-sand sediments at 30-50 m depth. The dominant taxa were Nassarius, Nucula, Macoma, Mulinia, Eurhomalea, Amphioplus magellanicus and species of Terebelidae. Orellana (1985) sampled the same three stations monthly for two years and obtained an average abundance of 5099, 5655, and 1362 individuals/m^2, and an average biomass of 433, 507 and 202 g/m^2 (wet weight) respectively.

A bottom sampling programme was carried out in 1986 at the mouth of the Aconcagua River. A grid of 16 stations was established along three transects at depths of 20-95 m from 1 to 9.2 km offshore. The sediments were muddy-sand and sandy mud, with organic matter ranging from 0.23 to 2.78%. The average results (Andrade, 1986a) were as follows: species density= 1606 ind./m^2; biomass= 68.5 g/m^2; specific diversity (H')= 1.73. Taxonomic similarity indexes (Sj) were also calculated and correlated with sediment types. The numerically most abundant groups were molluscs, polychaetes and crustaceans. The highest biomass was made up of molluscs and echinoderms. A total of 57 taxa were identified.

A separate sampling programme was conducted by Andrade and Alcazar (1986) in Valparaiso Bay on a grid of 20 stations seaward from a sewage outfall. Sediment types changed from sand to sandy-mud to mud from 10 to 50 m depth, with organic content ranging from 0.0 to 2.8%. The bottom communities had the following average characteristics: species density= 2342 ind./m^2; biomass= 129 g/m^2; specific diversity (H')= 1.88. A total of 68 taxa were identified, mostly to species. The polychaetes were numerically most abundant and bivalves accounted for the greatest biomass.

Gonzalez et al. (1976) sampled the bay of Quintero at 26 stations down to 60 m depth. 44 species of bivalves and gastropods plus 5 unidentified species were collected. The mean biomass was 23 g/m^2 wet weight, predominantly bivalves, and was related to the different sediment types and depths. The highest biomass occurred on sandy bottoms at 25-35 m depth. In over 21 stations from 5-50m depth, Andrade (1986b) identified 56 species, predominantly molluscs, crustaceans and polychaetes. The average community parameters were: species density= 758 ind./m^2; specific diversity (H')= 2.3.

Hard bottom communities

In 13 localities from Valparaiso Bay to Quintero Bay, 275 species of benthic macroalgae have been recorded (Instituto de Oceanologia, 1985).

Montemar, located in the central coastal zone of Valparaiso Bay, has been intensively studied because of its great variety of species and biotopes. The area has been protected from human intrusion. It has also been used for field experiments on the impact of chronic and catastrophic oil pollution on some intertidal communities (Leighton, 1986).

The first important study of the intertidal ecology of this area was that of Guiler (1959) who identified 15 species of algae and 74 invertebrates distributed in distinct fringes and bands. During the 1970's, studies on horizontal and vertical species distributions were intensified to identify local patterns of zonation (Alveal, 1970, 1971). Alveal (1970) identified 52 species of algae and showed that protected areas are generally characterized by the genera Lessonia, Adenocystis, Petalonia, Colpomenia and Scytosiphon. In exposed areas, red algae of the genera Gelidium, Dendrymenia, Polysiphonia and Iridaea, and the brown algae Lessonia and Durvillea were predominant. The tide pools were dominated by the genera Ulva, Chaetomorpha, Enteromorpha, Lyngbya and Bangia. Etcheverry (1986) cites 84 algal species at Montemar: Rhodophyta 50%, Phaeophyta 23.8%, Chlorophyta 20% and Cyanophyta 5.9%. He describes the seasonal occurrence of the different algae and the presence of reproductive organs. Recent SCUBA diving observations of the rocky subtidal environment at Montemar down to 20 m depth have identified 97 taxa of animals and algae (Redon and Alcazar, 1986).

Romo and Alveal (1977) studied the intertidal communities on rocky substrates near Quintero. They identified 31 species of algae and 78 species of benthic invertebrates. The highest biomass (160 g/100 cm^2, wet weight) corresponded to the Perumytilus purpuratus community on an exposed seafront, where 17 species were identified. The lowest biomass (2.42 g/100 cm^2) was found in a community of 8 species dominated by Gelidium pusillum at a protected site. The most common species was the bivalve Semimytilus algosus (465 ind./100 cm^2).

A study of an intertidal association between Chthamalus cirratus and Thalidium litorales has been initiated to compare the development of this community in different areas of the Valparaiso region that are exposed to different degrees of pollution (Instituto de Oceanologia, 1985).

Petroleum hydrocarbons

Sources of pollution

The principal sources of hydrocarbon pollution in the Valparaiso area are the following:

a) Shipping activities in the ports of Quintero, Valparaiso and San Antonio, amounting to 20% of the total for Chile. Around 1,800 ships move over 9 million tons of goods through these ports (Vio, 1983);

b) Quintero Bay has a crude oil unloading facility linked by a 20 km pipeline to a petroleum refinery at Con Con;

c) The Con Con petroleum refinery at the northern end of Valparaiso Bay produces gas, solvents, gasoline, kerosenes, diesel fuel, other fuels and asphalts. This facility has a waste water treatment plant where suspended and dissolved hydrocarbons are removed by flotation, sedimentation and oxygenation. After treatment these wastes are piped 800 m away from a sandy beach at a rate of 7,776 m^3/day (Boré et al., 1986);

d) There are refined petroleum product storage facilities in Las Salinas, Vina del Mar. These facilities are owned by private petroleum products distribution companies, which use several loading and unloading pipes moored about 200 m off the adjacent sandy beaches.

Between 1975 and 1985, oil spills totaling about 1,395 tons of hydrocarbons have been recorded in the area between Quintero and Valparaiso. An additional undetermined amount of hydrocarbons have been poured into the coastal area. Fines totaling US$ 220,000 have been charged for violations of pollution regulations, according to the Direccion General del Territorio maritimo y de Marina Mercante.

Pollution levels

A sampling programme to determine the dispersed/dissolved petroleum hydrocarbon concentrations in seawater was carried out in January, March, April and November 1985, and May, June, November and December 1986 using CPPS/UNEP methods. During this same period, measurements were made on marine organisms and sediments, together with beach monitoring for the presence of tar. A fixed station on the shore at Montemar permitted daily observations of floating hydrocarbon levels, and some complementary parameters concerning winds, waves, and ocean and air temperatures. Only three oil spill occurrences were observed from this station, but the amount of spilled oil could not be quantified (Instituto de Oceanologia, 1985).

Hydrocarbons have been observed on the beaches in the northern part of Valparaiso Bay and Quintero Bay. A severe earthquake in the area was one causal factor, since some of the intertidal beaches had over 90% of their exposed area coated with hydrocarbons. Hydrocarbon values in water, sediments and marine organisms are given in Table 4.

Table 4: Range of petroleum hydrocarbons in some areas of Valparaiso, 1985-1986 (Data from Instituto de Oceanologia, 1985; Alcazar et al., 1986; Andrade, 1986b; Comité Oceanografico Nacional et al., 1987)

Sampling site	Total Stations	Water (µg/l)	Sediment (µg/g)	Biota (µg/g)		Tar bal (g/m^2)
Zapallar	8	3 -29*				
Quintero	2	11 -19.6		Perumytilus	2.14-2.65	
	2	14 -56*		Eurhomalea	0.70	
	44	0.01- 7.2		Crassostrea	0.40	
	19		0.10-5.80	Pagurus	3.44-3.58	
Valparaiso	18	3 -66*				
	45	0.42-10				
beaches Zapallar to Valparaiso	16					0-2.5

* after an earthquake

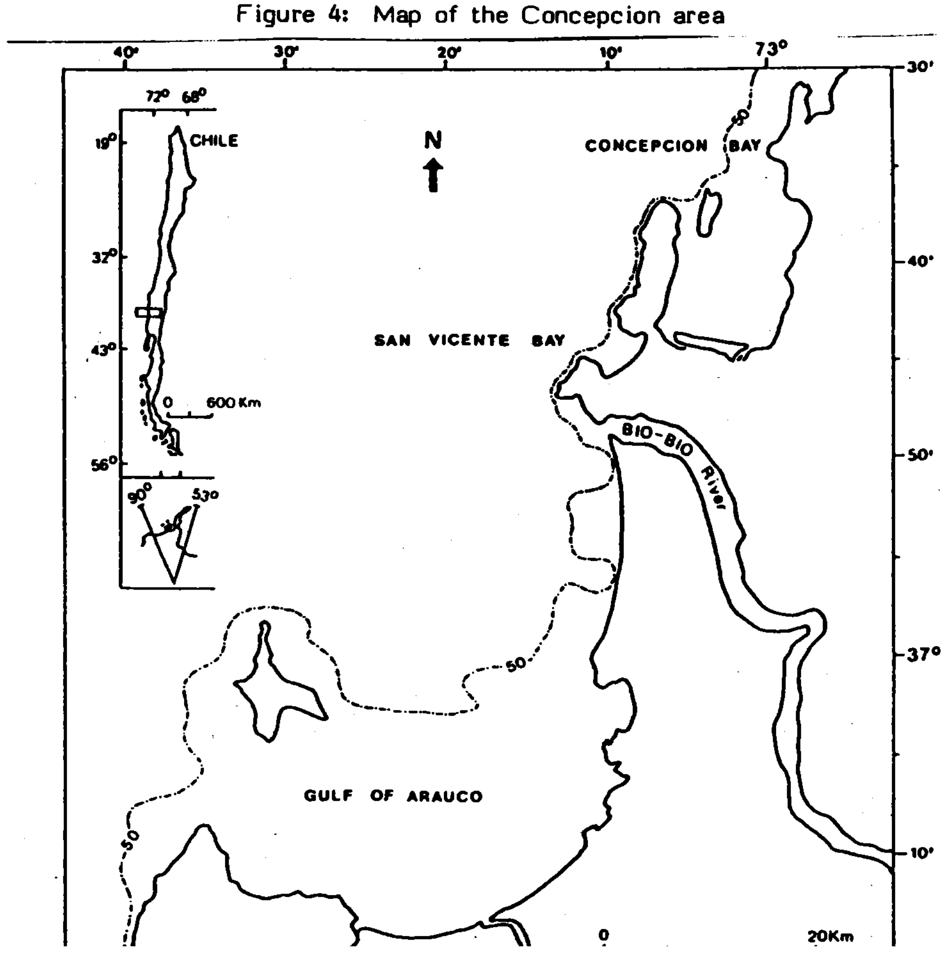
CONCEPCION BAY

Principal oceanographic features

Studies begun in Concepcion Bay in 1979 on hydrography, marine biology and pollutan levels have provided background information for the CONPACSE research programme o "Monitoring of marine pollution in Concepcion" (Universidad de Concepcion, 1980 and 1985).

The coastal area of Concepcion (36°30'-37°20' S) presents three important geographi features (Figure 4): Concepcion Bay, San Vicente Bay, and the Gulf of Arauco where the Bi Bio River discharges at a rate of 1,800 m^3/sec in the winter and an average annual flow c 900 m^3/sec.

Figure 4: Map of the Concepcion area



There are two water masses along the coast. The Sub-antarctic Surface Water (0-100m) has the following characteristics: sigma 25.0-26.0; temperature 11.5-13.5°C; salinity 34.0-34.3 $^{o}/_{oo}$; oxygenated with low nutrient levels. Below this is the Equatorial Subsurface Water with: sigma 26.5-26.8; temperature 8.5-11.5°C; salinity 34.5-34.8 $^{o}/_{oo}$; deoxygenated and rich in nutrients (Universidad de Concepcion, 1985).

Concepcion Bay is shallow with a surface area of approximately 170 km^2. During the spring and summer months, the south to south-west winds transport the subantarctic surface water off the coast, producing an upwelling of nutrient-rich equatorial subsurface water lasting for 7 to 8 months, resulting in high primary productivity (Bernal and Ahumada, 1985). The turnover rate for seawater within the bay varies from 2 days in spring and summer during upwelling to 22 days without upwelling in autumn and winter (Universidad de Concepcion, 1985). The high production during upwelling leads to a eutrophic, organically rich sediment that, together with the low oxygen concentration near the seafloor, produces hydrogen sulphide (50 µg at/l) in the bottom interstitial water (Bernal and Ahumada, 1985). At the end of the upwelling period, the total water column is saturated with oxygen, while sulphur is is detected only in the sediment (Bernal and Ahumada, 1985). Table 5 shows the characteristics of Concepcion Bay during periods of upwelling and downwelling.

Table 5: Characteristics of Concepcion Bay during upwelling and downwelling (data from Ahumada et al., 1983; Bernal and Ahumada, 1985)

	Upwelling	Downwelling
Duration	Late September - middle April	Late April - middle August
Salinity	>34.4 $^{o}/_{oo}$	<34.1 $^{o}/_{oo}$
Subsurface temperature	<11.5°C	>12.0°C
Subsurface oxygen	<1 ml/l	Total water column saturated
$N\text{-}NO_3^-$	>26 µmol/l	<3 µmol/l
$N\text{-}NO_2^-$	>1 µmol/l	<0.5 µmol/l
$P\text{-}PO_4^{-3}$	>2 µmol/l	<0.5 µmol/l
Water transparency	Low (high productivity)	High alternating with low (sediment from river runoff)
Discoloured water	Yes	No
Sulphur	Sulphide in bottom water	Elemental sulphur on the bottom sediment
Mass mortality	Periods of mass mortality of marine organisms	No mass mortality

Concepcion Bay has a depth of approximately 40 m. Its bottom is covered with black strong-smelling fine sediments and clays, especially during the summer months. The shallower borders of the bay are 10 to 15 m deep, with sand and sandy-mud (Gallardo et al., 1972). Between 4 and 35 m depth, the soft bottom benthos has an average biomass of 65 g/0.1 m^2 (wet weight, 1 mm mesh), made up principally of molluscs (81%) and polychaetes (15%). In fine sediment bottoms, polychaetes are numerically dominant (90%), while gastropods predominate in shallow sandy bottoms (Gallardo et al., 1972). Studies during 1986 confirm that the sublittoral benthos is dominated by sedimentary organisms, principally polychaetes, adapted to large variations in oxygen concentration and high levels of organic matter. The communities are simple, homogeneous and of low diversity (Gallardo and Carrasco, 1986).

A benthic sulphide system associated with deoxygenated waters has been reported off Concepcion at 32-64 m depth (Gallardo, 1976). Although it is poor in macrofauna, this system shows a certain abundance of small macrofauna and meiofauna dominated by polychaetes. The most conspicuous component is a complex community of procaryotes, predominantly filaments of the sulphur bacterium Thioploca. The biomass of these filaments at 64 m depth is about 16 g/0.1 m^2 (alcohol wet weight) or 5 g/0.1 m^2 dry weight (Gallardo, 1976).

The macrofauna of sandy beaches includes 22 species from 6 phyla, with an average of 192 individuals/m^2. Polychaetes are the most numerous (55%) followed by molluscs (25%) (Palma et al., 1982). The most frequent communities on rocky littoral substrates are those dominated by Perumytilus purpuratus, Iridaea laminarioides, Gigartina papillata and Ulva lactuca. A total of 36 species were recorded at 2 stations during spring and summer. The biomass of the Perumytilus population in spring was 50-150 g/400 cm^2 dry weight. In autumn, the biomass of Iridaea averaged 20 g/400 cm^2 dry weight. (Universidad de Concepcion, 1980).

The zooplankton standing stock has been estimated to range between 58 and 430 ml/m^2 between August and January. The minimum recorded was 2 ml/m^2 in October and the maximum was 1143 ml/m^2 in January (Arcos et al., 1980). The phytoplankton biomass, expressed as chlorophyll "a" concentration, ranged from less than 5 mg/m^3 to greater than 50 mg/m^3. The highest concentrations were measured during the summer months in association with high nutrient levels from upwelling (Ahumada et al., 1983).

Sources of pollution

The Conception region is the second most populous in the country with 1,516,552 inhabitants, of which 75.6% live in urban areas (Instituto Nacional de Estadistica, 1983). Shipping is an important activity, with ports handling 9 million tons of goods, not counting the fishing industry that uses Concepcion Bay as home port. The coastal area of Concepcion has a high population density, with important industrial and fishing activity. Human impacts may be an important factor in eutrophication in the marine environment (Universidad de Concepcion, 1985).

The Bio Bio River flows into the Gulf of Arauco not far south of Concepcion Bay. The river water is laden with sewage effluents from a population of 218,000, with an flow rate of 532 l/sec (Boré et al., 1986). Concepcion Bay receives 45 raw sewage discharges, with 9 alone conveying the sewage of 195,572 inhabitants (Universidad de Concepcion, 1986b). Table 1 shows the theoretical values for the organic load from the Concepcion area sewage system.

Table 6 shows the most important potentially polluting industries in the Concepcion area. These include 23 fish processing plants along the coast producing smoked, canned and frozen fish, and fish flour, with production amounting to 280,000 tons/year, while the total landings for industrial fisheries were 992,545 tons in 1985. Other industries in the area include textiles, glass, earthenware, and phosphate-based fertilizers (Universidad de Concepcion, 1986b). Industrial pollutants include cotton, wool, wood, synthetic fibres, argil, kaolin, iron residues, proteins, blood, animal fats, excrement, pectin, starch, maltose, glucose, wax, oil, paint, detergent, soap, lanolin, tannin, aniline, tar, phenol, alcohol; cyanic, oleic, linoleic, acetic and formic acids; urea, sodium and calcium hydroxide, ammonium, hydrochloric and sulphuric acids, sodium sulphide, sodium sulphite, hypochlorite, barium carbonate, ferrous salts, aluminium sulphate; salts of chrome, arsenic and copper; and mercury.

Table 6: Industrial pollution in the Concepcion area
Concepcion Bay, San Vicente Bay, Gulf of Arauco and Bio Bio River
(data from Boré et al., 1986; Universidad de Concepcion, 1980, 1986b)

Industry	Number	m^3/day
Paper, paper pulp	4	232,000
Textile	4	12,800
Asbestos-cement	1	7
Petrochemical	2	38,300
Glass	1	16
Glazed earthenware	1	1,200
Metallurgy	1	195,000
Shipyards		
Oil refinery	1	206,000
Plastics	1	
Fish processing	23	
Coal mines	3	
Slaughterhouses	8	
Coke gas factory	1	
Wood industry	2	
Tanneries		

The Concepcion area marine environment is considered to be one of the most heavily impacted in the country because of the combination of the quality and quantity of urban and particularly industrial effluents.

Pollutants

Since the beginning of the CONPACSE programme "Monitoring of marine pollution in Concepcion" in 1985, scientists from the University of Concepcion have made coliform counts, analyzed heavy metals and pesticides in seawater, sediments and marine organisms, and continued research on the hydrography of the bay. The results of the first sampling campaign in summer at the beginning of 1985 are given in Table 7.

Table 7: Pollutants in Concepcion Bay, Summer 1985
Total stations in parentheses. (from Universidad de Concepcion, 1985)

	Water	Sediment	Organisms: Aulacomya	Organisms: Perumytilus
	ppb (5)	ppm dry wt (4)	ppm dry wt	ppm dry wt
Hg	0.210 - 1.10	<0.01 - 0.24	0.10 - 0.16	0.041 - 0.13
Cd	0.023 - 1.10	<0.04 - 3.10	3.20 - 8.40	6.7 - 16.7
	ppb (8)	ppb dry wt (6)	ppb dry wt	ppb dry wt
DDT	0 - 0.090	0 - 1.391	2.612 - 8.205	5.064 - 6.319
DDE	0 - 0.015	0 - 2.124	5.374 - 20.328	10.417 - 24.375
Lindane	0 - 0.020	0.053 - 0.531	0.331 - 1.097	0 - 1.828
Aldrin	0	0	0 - 0.953	0.242 - 0.340
	MPN/100 ml (14)		MPN/100 g	MPN/100 g
Total coliforms	0 - 1,100		1.82 - 48.0	30.0
Faecal coliforms	0 - 1,100		0 - 8.6	1.82 - 18.6

The spring sampling campaign in late 1985 was based on the results obtained during the summer of 1985. Special emphasis was given to those sites receiving a larger input from terrestrial sources. The methods used were also improved as follows: water samples were obtained with Teflon instead of Tygon hoses and they were not filtered on board; and water samples for pesticide analysis as well as samples of sediments and marine organisms were obtained by SCUBA diving. The results of the spring 1985 campaign are given in Table 8.

Table 8: Pollutants in Concepcion Bay, Spring 1985
Total stations in parentheses. (from Universidad de Concepcion, 1986a)

	Water	Sediment	Organisms: Aulacomya	Organisms: Perumytilus	Sewage
	ppb (10)	ppm dry wt (6)	ppm dry wt	ppm dry wt	
Hg	0.23 - 0.43	1.35 - 4.97	0.052	0.098	
Cd	0.06 - 1.05	0.10 - 0.84	3.264	28.7	
	ppb (7)	ppb dry wt (6)	ppb dry wt	ppb dry wt	ppb
DDT		0.045 - 0.160	11.64	4.83	0.0150
DDE	0.006	0.009 - 0.210	6.96	2.21	0.0280
Lindane	0.010 - 0.021	0.024 - 0.097	0.426	0.410	0.0041
Aldrin		0.045 - 0.140	0.148	0.088	0.0036
Dieldrin			0.489	--	0.0058
	MPN/100 ml (7)		MPN/100 g	MPN/100 g	
Total coliforms	39 - 1,100		6.0	6.0	
[illegible]	[illegible]		[illegible]	[illegible]	

Table 9: Mean levels of trace metals and pesticides in Concepcion area, 1979
(data from Universidad de Concepcion, 1980)

	Water (ppb)						Sediment (ppm)			Organism: *Aulacomya ater* (ppm)		
Stations:	Concepcion (11)		San Vicente (8)		Arauco (10)		Concepcion (9)	San Vicente (6)	Arauco (6)	Concepcion	San Vicente	Arauco
	Autumn	Spring	Autumn	Spring	Autumn	Spring						
Hg	1.60	0.27	0.31	0.13	0.31	0.19	0.15	0.38	0.25	0.19	0.14	0.24
Cd	0.06	0.07	0.16	0.06	0.19	0.12	6.27	3.05	2.24	3.75	5.80	6.50
Pb	0.30	0.15	0.38	0.30	0.12	0.19	40.40	17.35	14.68	1.16	0.25	1.05
Ni	0.90	0.60	0.67	0.64	1.26	0.51	23.72	45.63	17.46	1.20	1.40	1.40
Ag	0.03	0.04	0.004	0.17	0.04	0.04	2.32	2.49	1.56	0.09	0.07	0.10
Cu	0.60	0.70	0.56	0.58	0.65	0.56	40.79	27.73	23.61	8.15	6.10	8.15
Fe	12.60	12.30	5.57	15.70	2.92	9.05	4,800.00	39,700.00	30,800.00	222.73	379.00	681.00
Zn	2.32	3.50	--	5.13	2.98	2.06	91.77	77.60	58.88	71.43	96.00	103.00
Mn	--	5.00	2.29	3.50	0.97	1.51	245.68	472.23	256.96	5.69	12.00	13.50
							ppb	ppb	ppb	ppb	ppb	ppb
DDT	0.50	0.40	0.70	0.70	0.80	1.00	4.50	3.60	3.20	14.30	9.40	21.80
DDE	0.06	0.15	0.66	0.20	0.19	0.20	1.10	0.50	0.50	5.10	2.90	6.10

The methods used in this monitoring programme are the standard methods described in the following documents: CPPS/UNEP, 1983a, 1984; UNEP/FAO/IOC/IAEA, 1984a, 1984b, 1984c; UNEP/IAEA, 1982, 1985a, 1985b; UNEP/WHO, 1983 (Universidad de Concepcion, 1986a).

The observed differences in the results between the summer and spring campaigns may be due to the differences in effluent inputs and to the different hydrographic conditions in each season (Universidad de Concepcion, 1986a). The results of measurements made in 1979 in the Concepcion area are included in Tables 9 and 10 for comparison with the more recent data.

Table 10: Coliform counts in seawater in Concepcion area, 1979 (MPN/100 ml) Total stations in parentheses. (from Universidad de Concepcion, 1980)

Sampling site	Season	Total Stations	Total coliforms (MPN/100 ml)	Total Stations	Faecal coliforms (MPN/100 ml)
Concepcion Bay	Autumn	4	3 - 1,000	4	3 - 1,000
		1	1,001 - 10,000	2	1,001 - 10,000
		7	10,001 - 11,000	6	10,001 - 11,000
	Spring	1	186 - 1,000	2	4 - 1,000
		1	1,001 - 10,000	3	1,001 - 10,000
		8	10,001 ->11,000	5	10,001 - 11,000
San Vicente Bay	Autumn	3	18 - 1,000	5	3 - 1,000
		3	1,001 - 10,000	2	1,001 - 4,120
		1	11,000		
	Spring	4	23 - 1,000	4	3 - 1,000
		1	>11,000	1	5,150
Gulf of Arauco	Winter	7	3 - 1,000	8	3 - 1,000
		1	1,001 - 10,000	1	6,700
		1	11,000		
	Spring	4	18 - 1,000	6	2 - 1,000
		2	1,001 - 10,000	2	1,001 - 7,800
		2	10,001 ->11,000		

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CRITICAL AREAS, VULNERABLE RESOURCES AND PROTECTION PRIORITIES AGAINST OIL POLLUTION IN THE SOUTH-EAST PACIFIC

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ABSTRACT

In 1983 the governments of Colombia, Chile, Ecuador, Panama and Peru adopted a Supplementary Protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or other Harmful Substances, in the framework of the Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific. Article II of the Protocol describes the contents of national contingency plans to combat oil pollution, including the selection of the areas most vulnerable or sensitive to ecological or economic damage which will require special protection.

This paper describes the critical areas, vulnerable resources and protection priorities against oil pollution on the Pacific coasts of Colombia, Chile, Ecuador, Panama and Peru based on a sensitivity index, associated economic and ecological considerations, and related interests of a coastal state that could be affected by oil pollution.

Introduction

In 1981 the Governments of Colombia, Chile, Ecuador, Panama and Peru adopted an Action Plan for the Protection of the Marine Environment and Coastal Areas of the South-East Pacific (UNEP/CPPS, 1981), one of the eleven geographical regions where the United Nations Environment Programme (UNEP; PNUMA in Spanish) promotes the implementation of Regional Seas Action Plans. The First Intergovernmental Meeting under the Plan, held in Quito, Ecuador, in July 1983, approved the development of two programmes of regional interest which came to be known jointly as Co-ordinated Programmes of Monitoring and Research on Marine Pollution in the South-East Pacific - CONPACSE, and implemented a Regional Contingency Plan to Control Oil Spills. The meeting also adopted a Protocol for the Protection of the South-East Pacific against Pollution from Land-Based Sources, which has since been ratified by the Governments of Colombia, Chile, Ecuador and Panama and entered into force on 14 July 1986, together with a Supplementary Protocol to the Agreement on Regional Co-operation in Combating Pollution of the South-East Pacific by Hydrocarbons or Other Harmful Substances, which entered into force on 20 May 1987 upon ratification by Colombia, Panama and Chile (UNEP/CPPS, 1987a).

Annex VIII to the Regional Contingency Plan (UNEP/CPPS, 1986) lists essential topics which must be part of a National Contingency Plan, including priority, protection areas, priority maps, and the Supplementary Protocol. Article II of this protocol, dealing with the description of a National Contingency Plan, sets forth the following aspects which, among others, must be included in a plan:

--- selection of the areas most vulnerable or sensitive to ecological or economic damage which will require special protection;
--- the natural, atmospheric and marine conditions prevalent in such vulnerable areas; and
--- optimum control and clean-up methods in various circumstances and vulnerable areas.

Furthermore, the Intergovernmental Meeting held in July, 1983, approved the selection of critical areas for oil pollution within the Regional Contingency Plan. It also entrusted the CPPS, with the support of UNEP, with the task of assisting the Governments participating in

Criteria for identification of critical areas

There is a broad spectrum of criteria and categories which can be used to classify those areas which, on account of their location, uses and/or ecological characteristics, could be affected adversely by human activities, and therefore demand special concern. These areas have been called Particularly Sensitive Areas (IMO), Special Areas (IMO), Vulnerable Areas (IOC), High Risk Areas (GESAMP), Biosphere Reserves (UNESCO), etc.

Some guidelines have been proposed to help in the identification and selection of these different types of areas, while others aim to classify them according to their degree of sensitivity. For those areas defined as coastal water areas, their sensitivity and/or vulnerability, together with the uses made of them, are the criteria most frequently used in the selection of critical areas for accidental oil pollution.

As part of the task of identifying critical areas in cases of accidental oil pollution in the South-East Pacific, research has been done on the Pacific coastal resources of Colombia, Chile, Ecuador, Panama and Peru to evaluate the possibility of their being polluted by oil. This analysis has been performed on the basis of three different factors which are combined to identify the so-called "critical areas". These are:

--- their worth;

--- their sensitivity to oil pollution; and

--- the risk of their being adversely affected by an oil spill.

The **worth** of a critical area is set by each country according to a standard based on its national priorities as incorporated in the particular classification system used by the national bodies entrusted with the administration of the resources existing in the area.

Sensitivity is measured in terms of a sensitivity or vulnerability index based on a geomorphological classification of the coastline, the behavior of spilled oil, and the uses of the area involved. Table 1 shows the sensitivity index according to types of coast, ranked according to increasing susceptibility to ecological damage from oil pollution.

Table 1: Sensitivity Index (IS)

Type of coast	IS
Exposed, highly sloping, rocky cliffs, man-made structures	1
Wave-cut platforms, often with shores of mixed sand and gravel	2
Gently-sloping exposed shores, loose grain sands	3
Sloping shores on open coast, coarse-grained sands with depressions	4
Firmly compacted exposed shores, impermeable muds and fine sand terraces	5
Mixed fine sand and gravel shores, usually with inclined profiles and active cover	6
Pebble, gravel and boulder shores, often with projecting cliffs	7
Protected rocky coasts with depressions on sheltered shores	8
Intertidal mud-flats in estuaries and harbours	9
Protected salt marshes, mangroves and coral reefs	10

The risk is a measure of the probability of being adversely affected by an oil spill. It includes both the probability that spilled oil could have a serious economic or ecological effect on activities or resources in the area (Table 2), and the risk of an oil spill taking place (Table 3). Since maritime transportation may contribute in large measure to this criterion, it can vary with the magnitude of the traffic and with changes of routes.

Table 2: Areas with high risk of damage from oil pollution

Type of area according to use	Description	Uses
Marine resources areas	Fish	Fish culture facilities
	Shellfish	Shellfish raising areas
	Water birds	Nesting areas
	Mammals	Resting areas
	Plants	Areas of cultivation
Water supply areas	Domestic	Drinking water systems
	Industrial	Processing water systems
	Irrigation	Supplies for agriculture or forest irrigation
	Public services	Fire hydrants
Recreation areas	Direct contact with water	Bathing beaches
	Indirect contact with water	Pleasure boating areas
Areas of commercial activity	Shellfishing	Shellfish beds
	Seaside tourist resorts	Hotels and restaurants
	Small boat anchorages	Marinas and docks
Industrial areas	Transport	Navigation routes
	Electricity/communications	Electric cables and towers
	Resource extraction	Oil platforms
Natural ecosystems	Marine	Sandy beaches
	Estuarine (low salinity)	Marshes and shellfish beds
	Lacustrine (fresh water)	Shallow mangroves
	Riverine	Sections with rapid currents
	Swampy	Coastal marshes

Table 3: Areas with high risk of causing oil spills

HIGH OIL SPILL POTENTIAL
- Navigation routes
  - Heavy traffic zones
  - Dangerous navigation zones
- Off-shore oil exploration/production areas
- Submarine pipeline networks
- Maritime terminals
  - Monobuoys
  - Harbours
  - Ports

MODERATE OIL SPILL POTENTIAL
- Coastal oil refineries
- Reception facilities for oil residues and dirty ballast
- Coastal oil storage areas
- High domestic waste discharge areas
- Submarine oil storage wells
- Natural submarine oil seeps

Information used to identify critical areas

The following types of information have been used in the South-East Pacific to identify critical areas in case of accidental oil pollution:

Distribution of main commercial fish species: the geographic areas occupied by the main groups or categories of fish of commercial value, in terms of the importance of the catch, usually accompanied by the scientific and common names, catch statistics and catch sites.

Mariculture areas: mainly crustacean, mussel and algal cultures, including location and areas involved together with information on types of activity (industrial and/or artisanal methods) and annual yields.

Catch methods: apart from data on catch sites, information is collected on catch methods including the following categories: bottom dredging, trawling, line fishing, netting, and purse seining.

Coastal mining: development of coastal mineral resources at three levels: small scale, medium scale and extensive mining operations, with additional information on the kinds of resources exploited, types of exploitation and production figures.

Marine birds and mammals: only seabirds and marine mammals from dominant groups and using different habitats, with additional information on ecological characteristics such as nesting areas, breeding seasons, migration patterns, scientific and common names, and economic value of the species concerned.

Location of natural parks, reserves, specially protected areas, wildlife sanctuaries, tourist reserves, places of historic value: including information on areas, current legislation, administering institutions, allowed uses, type of tourism allowed, periods of time and seasons for permitted uses.

Ports, coastal cities, roads, maritime terminals, navigation aids: with information on population, political and administrative situation of ports, prevailing economic activities, public services infrastructure (airports, hospitals, etc.), lighthouses, buoys, dock berths, ship channels, etc.

Oil terminals, pipelines, loading buoys, coastal refineries, storage tanks: including types of refineries, volumes of oil transported, types of oil products, storage capacity, security systems, contingency plans, etc.

Maritime traffic routes, bathymetric information: including information on route lines, compulsory traffic routes, commercial anchorages, marine fleet tonnage, statistics on traffic and movement, bathymetry of shallow waters less than 45 m deep.

Shallow and coastal currents, tidal ranges: speed and direction of shallow currents, particularly those formed by winds (current speed indicated by length of arrows symbolizing currents).

Sensitivity: the sensitivity (or vulnerability) index based on the physical and geomorphological characteristics of the coast and their interaction with the behavior of oil as a pollutant, showing the capacity for recovery of oil polluted areas: 6-10 is a high sensitivity index; 1-5 indicates low sensitivity.

Results

This paper shows the results in map form, with symbols representing the resources, activities and corresponding sensitivity index. The resulting maps show critical areas only; they are not maps of coastal marine resources and do not replace thematic maps. They only depict generalized information on those resources which could be endangered by an oil pollution accident. Such maps provide in a reliable, visual and easily understood form the information on existing critical areas as identified by Colombia, Chile, Ecuador, Panama and Peru.

Colombia

Map 1 shows the critical areas and vulnerable resources in case of oil pollution along the Pacific coast of Colombia. The Colombian coast, 1,300 km long, shows two distinctive sectors. North of Cape Corrientes, the coast is high and rugged, with a broken shoreline, peaks and hillsides, and slopes subject to active landslides. The second sector has a low coastline subject to frequent flooding, covered by mangrove swamps and crossed by ditches and streams. Both ends show high sensitivity (IS = 9), with low wind energy and high biological productivity. Pollution in these two areas may be persistent, and is not considered cleanable by mechanical means. In the mid-coast area (IS = 5), there is high tidal fluctuation, and cleaning procedures should be restricted to manual methods. Two critical areas at high risk are located here: the Bay of Buenaventura and Tumaco Cove (UNEP/CPPS, 1987b).

Chile

Maps 2, 3 and 4 illustrate the critical areas, vulnerable resources and protection priorities against oil pollution in Chile. There are four critical areas. The "A" area between Mejillones and Chanaral includes 395 km of coast between Antofagasta and Atacama provinces in the Second and Third Regions of Chile. The coast mainly has a sensitivity index of 3, with gently sloping shores and fine sand. In those places where the mechanical removal of pollution is deemed appropriate, the use of heavy machinery and simple tools is feasible. The "A" sector has places where boulders, stones and gravel occur subject to quick and deep penetration of oil with a severe environmental impact (UNEP/CPPS, 1987c).

The "B" zone, located between Zapallar and Valparaiso, comprises 60 km of coast in the Fifth Region, including the maritime terminals of Quintero, Vina del Mar and Valparaiso with the highest shipping figures in the country. The coasts in this sector have a sensitivity index ranging from 1 to 3, with exposed, steep rocky cliffs or narrow gently sloping shores with fine sand. Tidal reflection from coastal cliffs may hold back oil, allowing for cleaning procedures to be implemented, while on gently sloping shores, mechanical removal procedures are advisable.

The 80 km sector classed as zone "C" is in the Eighth Region between Tome and Lota. It has characteristics similar to zone "B" described above. Zone "D" is the eastern section of the Strait of Magellan (Map 4) in the Twelfth Region, including the eastern mouth of the Strait between Magellan Province and Terra del Fuego. It is an area of active oil exploration. The coasts have sensitivity indexes of 6-7, with steep shores and active tops composed of large pebbles, boulders and gravel mixed with fine sand and gravel, subject to quick penetration by oil. Erosive damage following cleaning is significant. Cleaning procedures are difficult to implement and rather expensive because of the inaccessibility which prevents installation of the appropriate equipment.

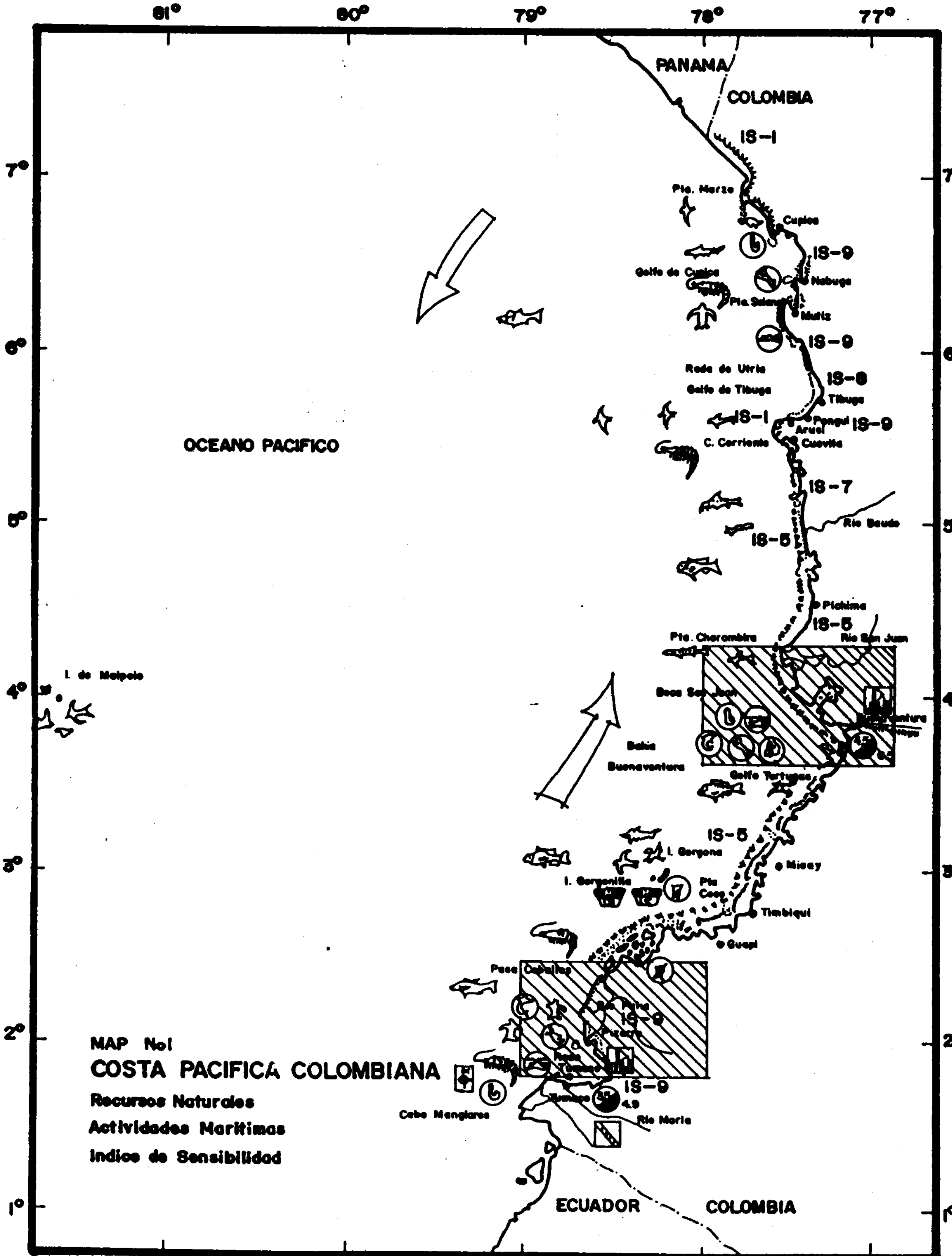
Ecuador

Maps 5, 6, 7 and 8 show critical areas and protection priorities against oil pollution accidents in Ecuador. Two critical areas can be identified by their larger number of vulnerable resources: the Gulf of Guayaquil, and a well-defined area north of the Esmeraldas region. Both areas have coasts with salt marshes protected by mangrove swamps, with muddy tide flats and estuaries, providing well-protected habitats with high biological productivity. Cleaning of these shores is not recommended, even in the case of severe environmental impact. The use of mechanical oil clean-up equipment should be avoided, with preference given to suction equipment, booms or other containment equipment, and dispersants.

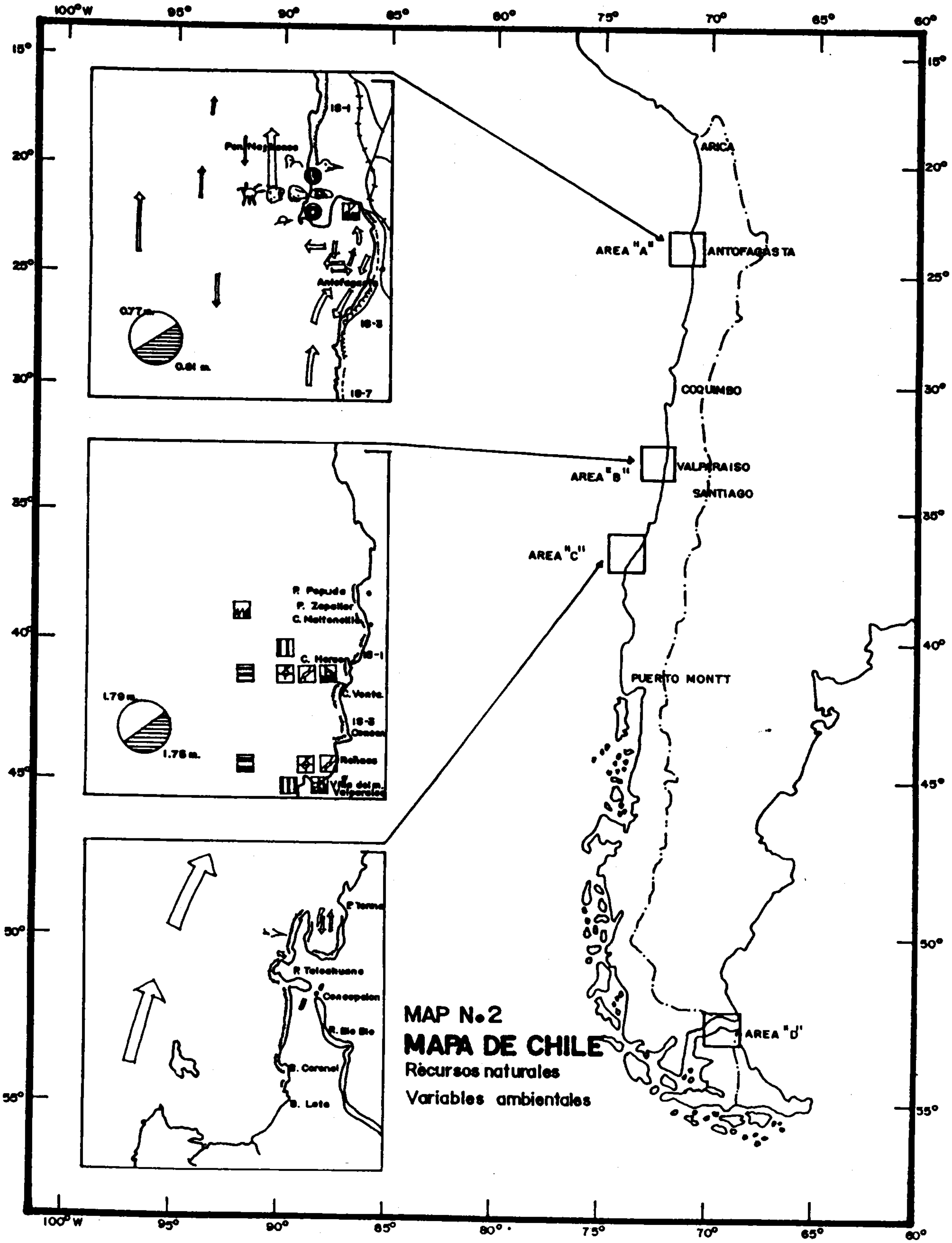
The rest of the coast has exposed gently sloping shores of fine sand with a sensitivity index of about 3. Some penetration of oil into the sediment can be expected, with some mortality of the adjacent shallow benthos (UNEP/CPPS, 1987d).

There are other high risk areas, such as the Esmeraldas-La Libertad traffic routes, La Libertad-Manta and Esmeraldas-Guayaquil. Areas such as the Bay of Caraquyez, the Santa Elena Peninsula and Puerto Bolivar are considered potentially sensitive. The Galapagos Archipelago (Map 8), because of its particular characteristics, has been classed a high risk priority area to be protected against oil pollution accidents.

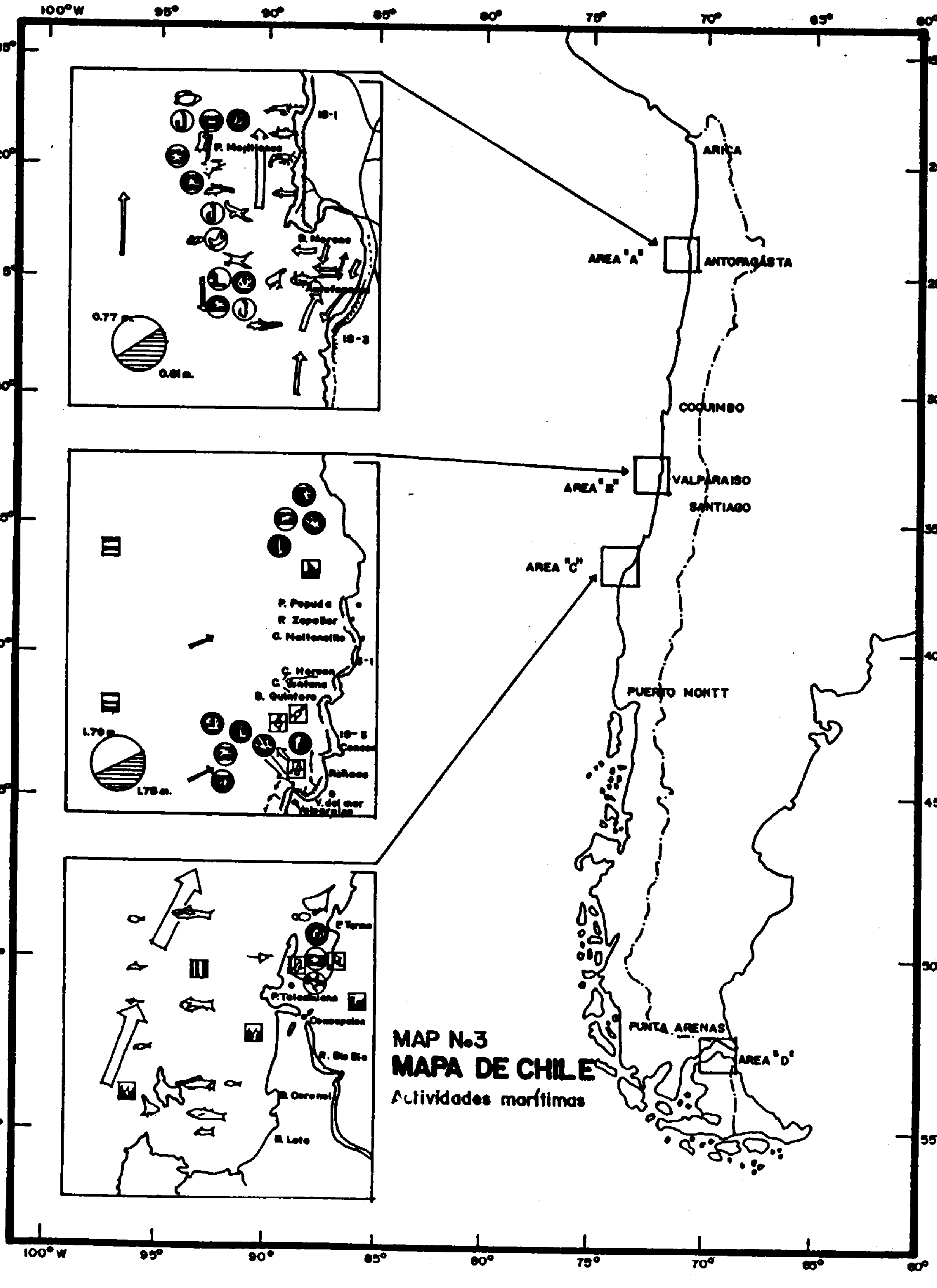
Map 1: Pacific coast of Colombia, showing natural resources, marine activities, sensitivity index (IS) and critical areas (hatched)



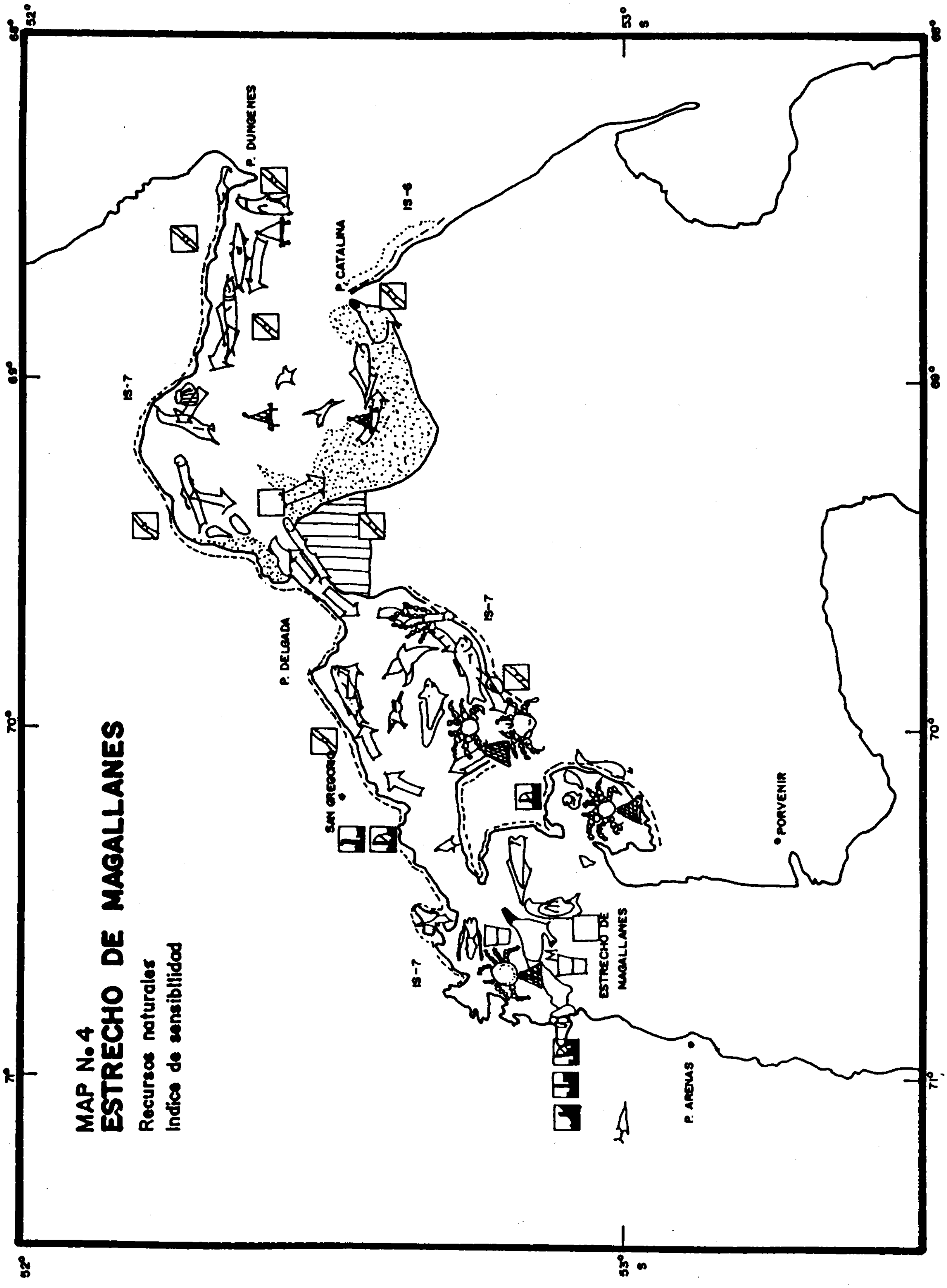
Map 2: Critical areas of Chile, showing natural resources and environmental factors



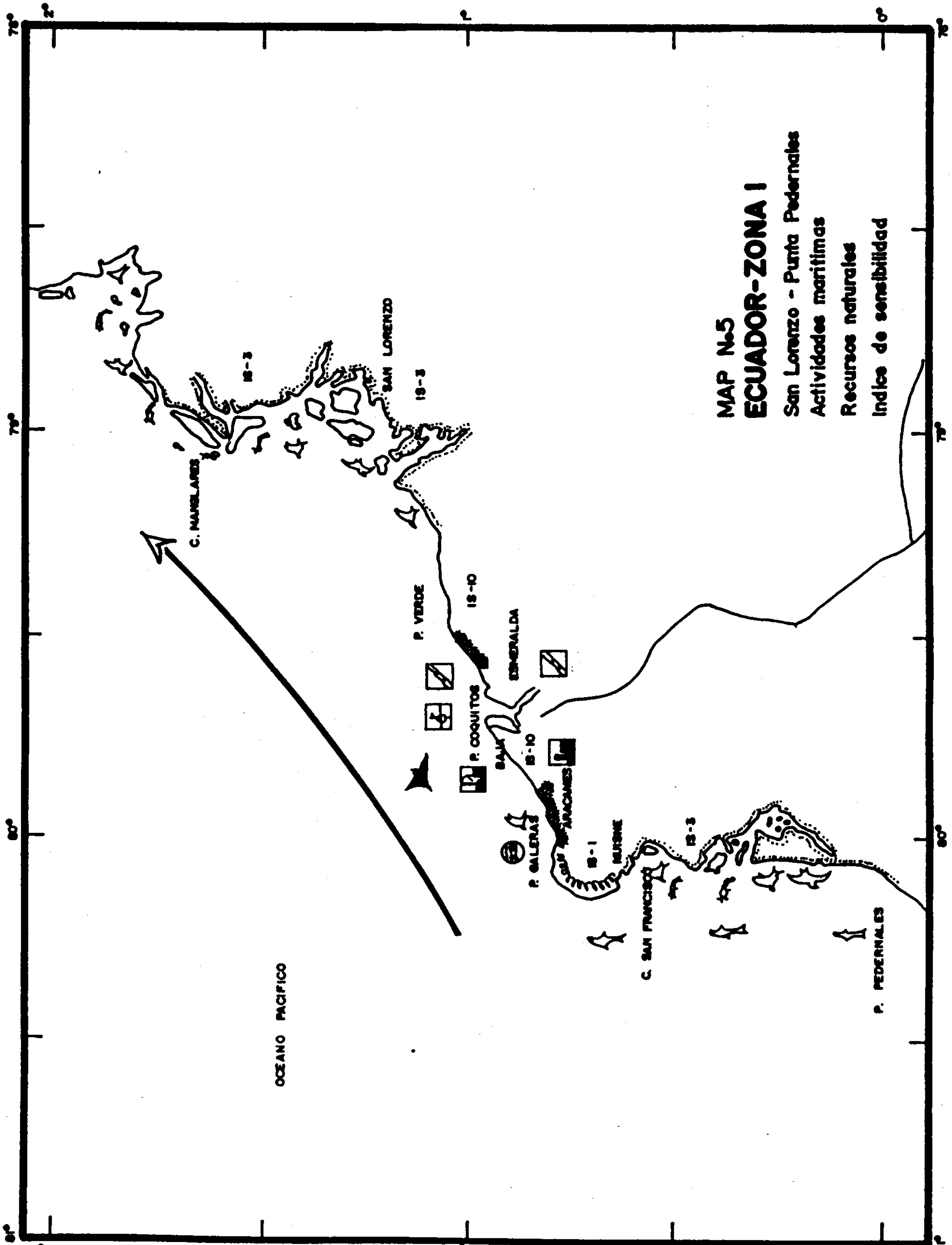
Map 3: Critical areas of Chile, showing marine activities



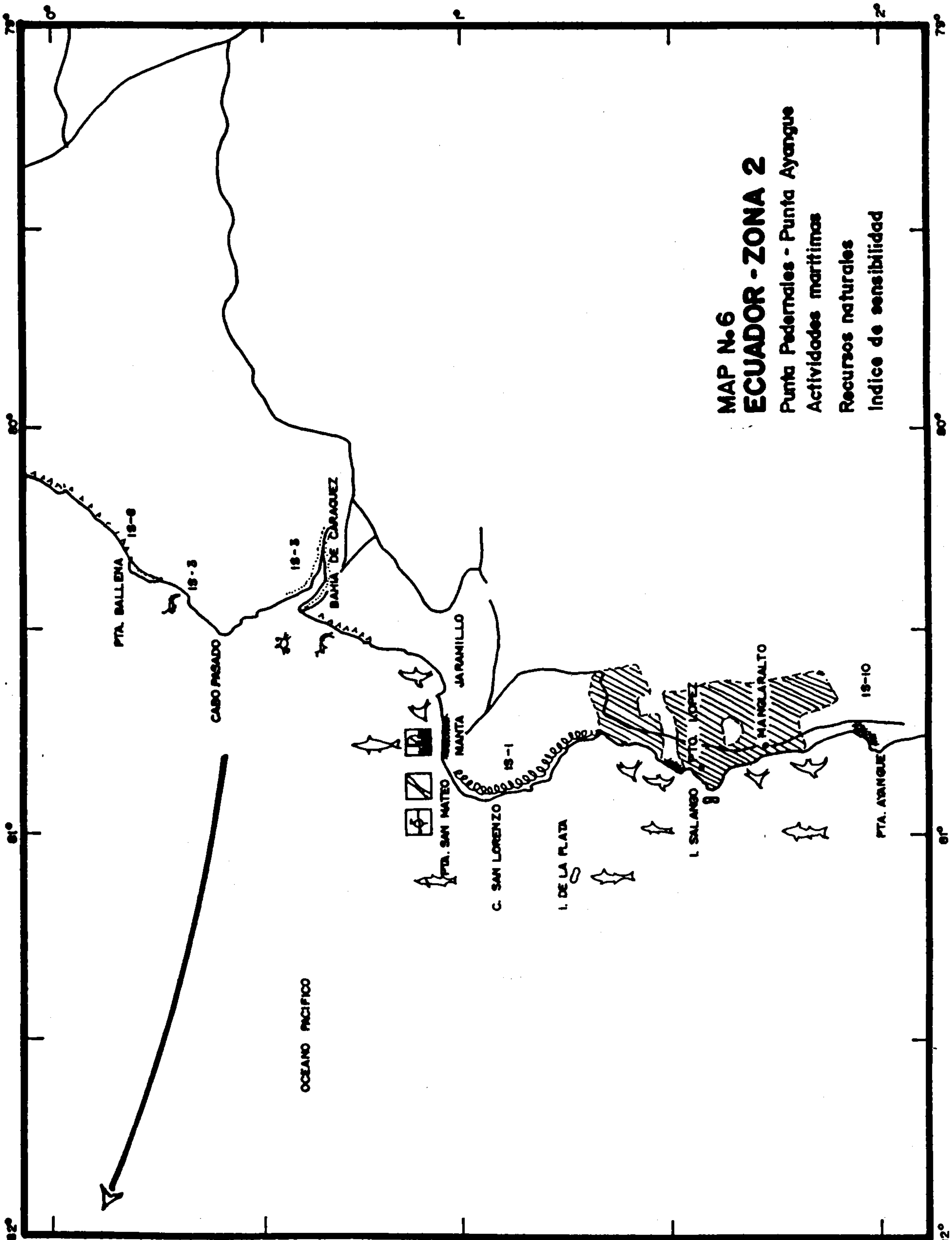
Map 4: Strait of Magellan, Chile, showing natural resources and sensitivity index (IS)



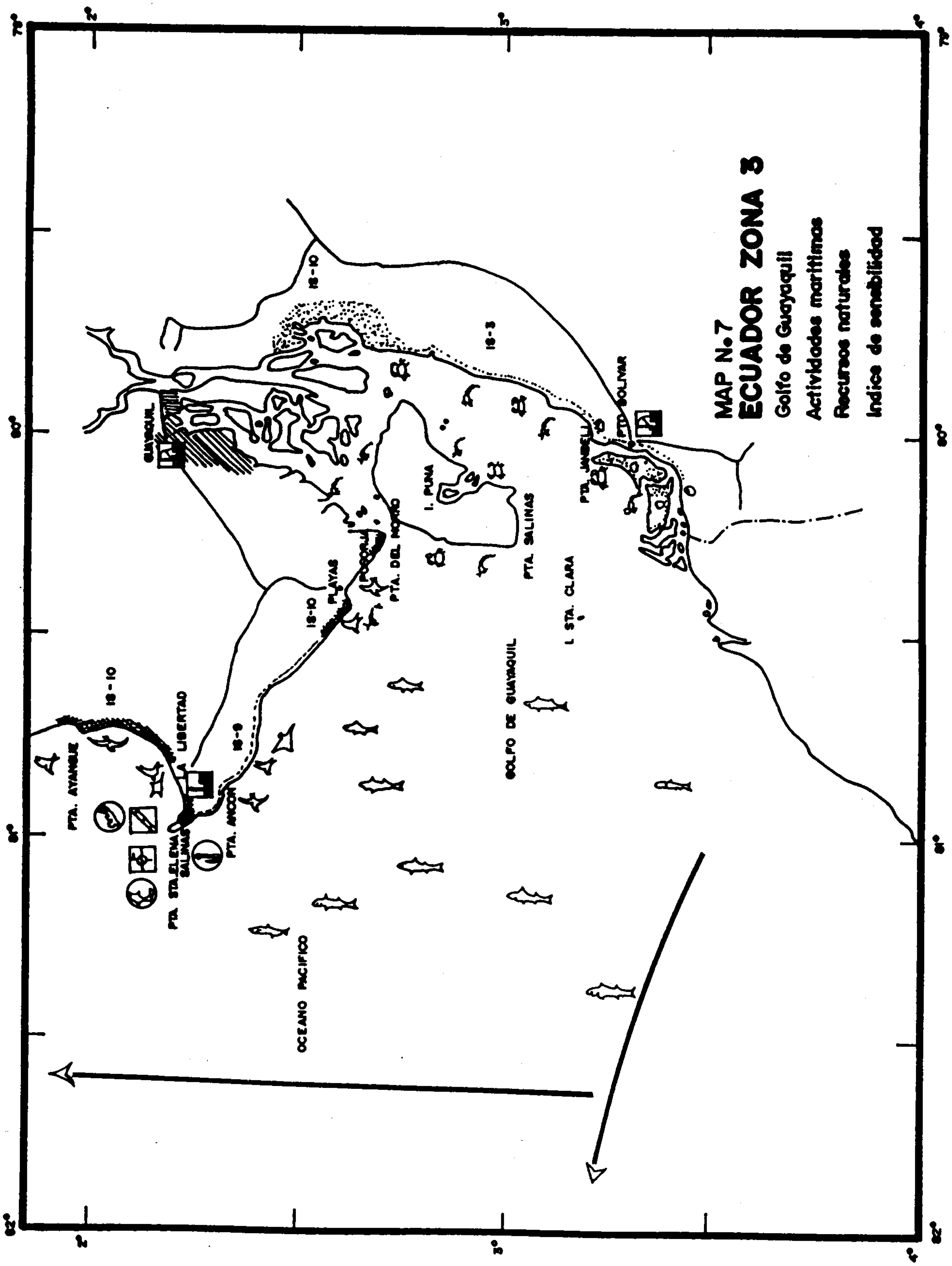
Map 5: Ecuador - zone 1 (San Lorenzo-Point Pedernales) showing maritime activities, natural resources and sensitivity indexes (IS)



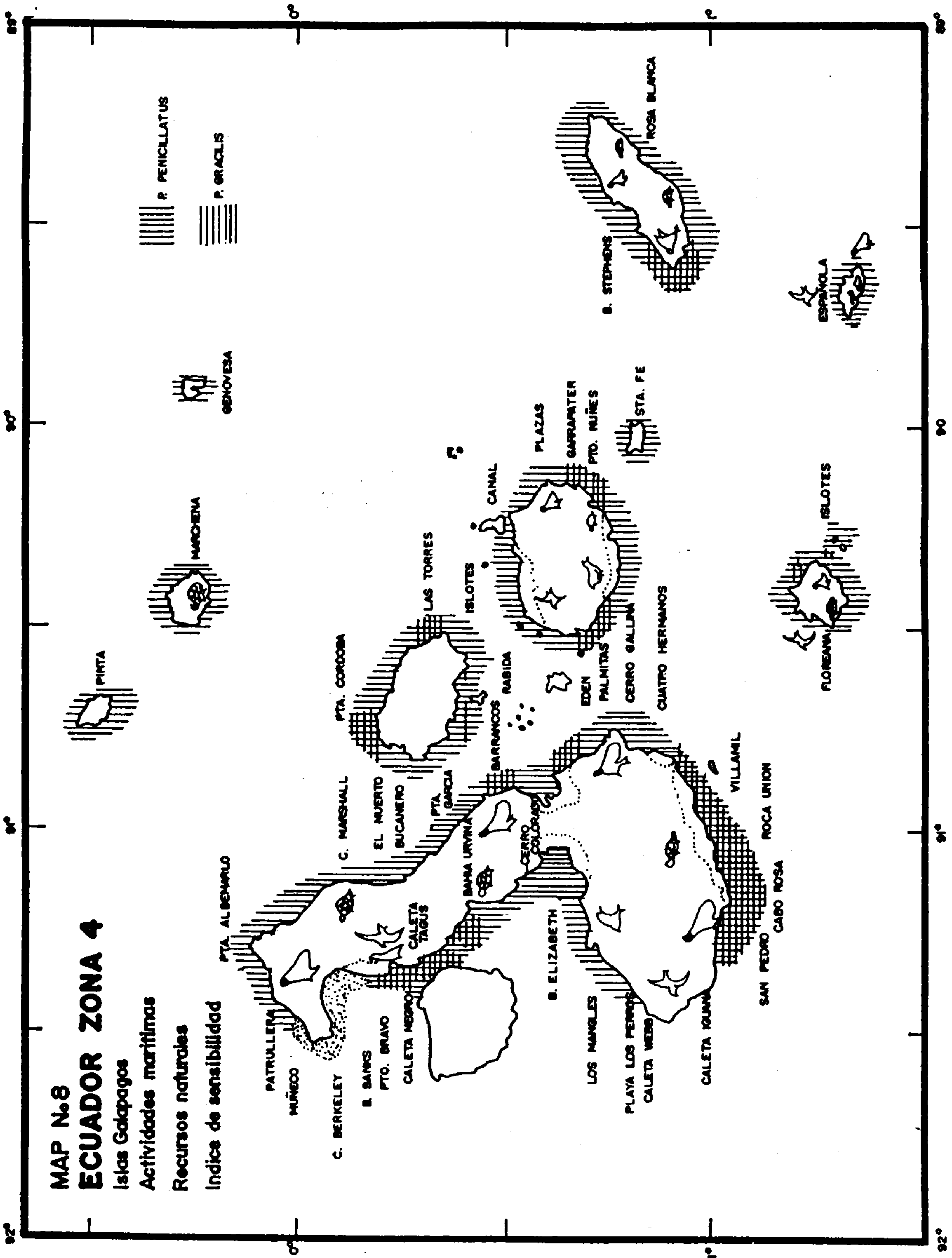
Map 6: Ecuador - zone 2 (Point Peternales-Point Ayangue) showing maritime activities, natural resources and sensitivity indexes (IS)



Map 7: Ecuador - zone 3 (Gulf of Guayaquil) showing maritime activities, natural resources and sensitivity indexes.



Map 8: Ecuador - zone 4 (Galapagos Islands) showing maritime activities, natural resources and sensitivity indexes



Panama

The critical areas, vulnerable resources and protection priorities for the Pacific coast of Panama are shown in Maps 9 and 10. The following critical areas can be identified: the western Gulf of Panama, Puerto Armuelles and the Port of Vacamonte. The coasts of the Gulf of Panama are broken, with places with high potential for mariculture development, with low wind energy, high biological activity and a sensitivity index of around 9. In the event of an oil spill, these areas should be protected by containment equipment, by suction equipment and duly dosed dispersants; mechanical cleaning is not recommended regardless of the severity of environmental impact (UNEP/CPPS, 1987e).

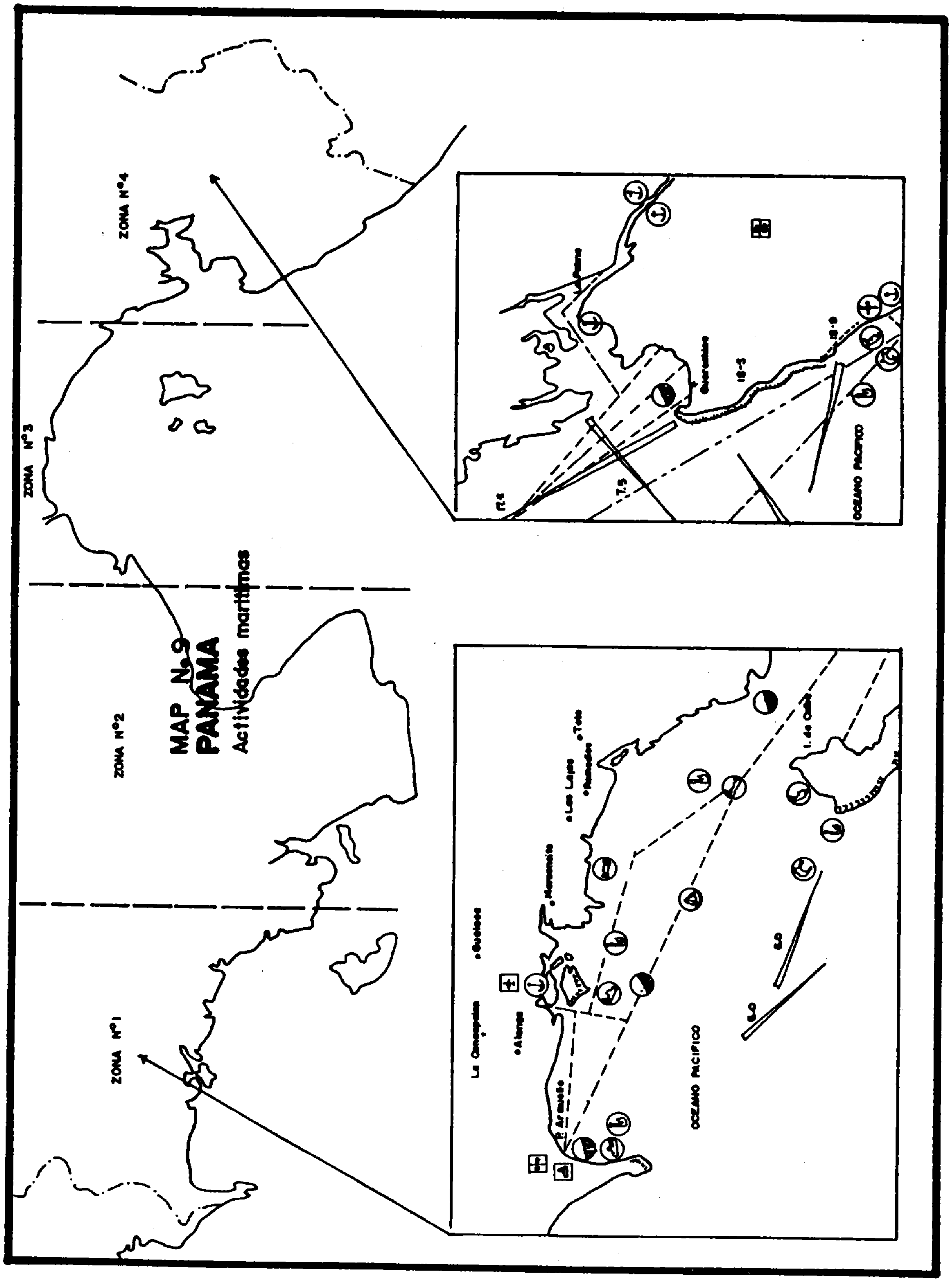
Peru

Maps 11, 12 and 13 illustrate critical areas of the Peruvian coast sensitive to marine oil pollution. Three critical areas and three potentially sensitive areas have been identified. Critical area 1 (AC-1) is located on the north Peru coast between Punta Capones and Punta Aguja along 24 km of coast with a second degree upwelling zone. The region is characterized by a large number of small inlets and fishing ports, as well as eighty-four offshore oil drilling and extraction platforms. Critical area no. 2 (AC-2) on the central coast includes a 24 km coastal strip between Vegueta Inlet and the mouth of the Rio Lurin, with a fourth degree upwelling zone. It is the site of oil unloading ports, the industries of the Callao area, and the Conchan and Pailla refineries. Critical area 3 (AC-3) is south of area 2 between Port Tambo de Mora and Punta Azua along 24 km of coastline with a second degree upwelling area.

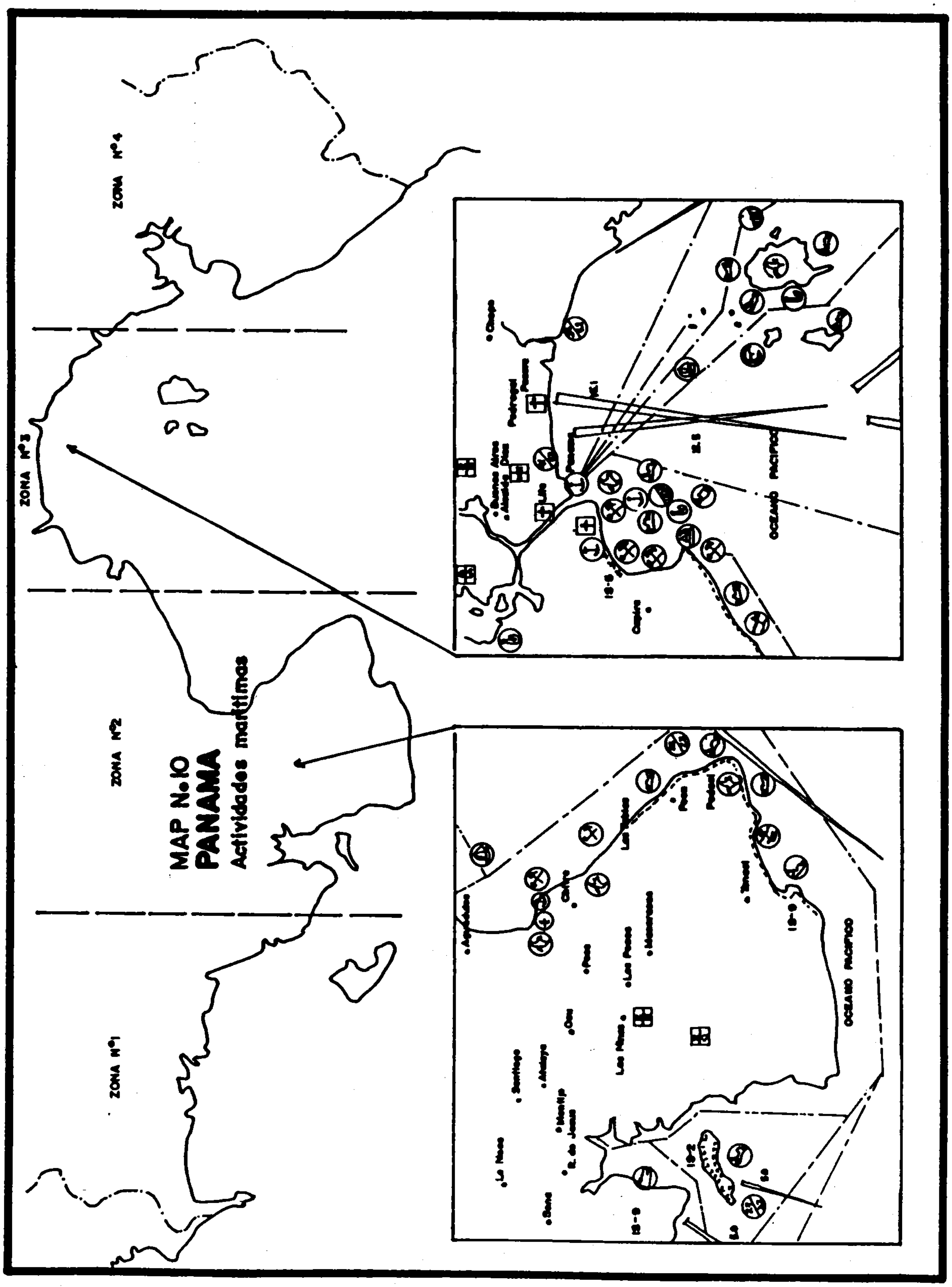
The three sensitive areas are: sensitive area no. 1 between Eten Port and Samanco Port, with shores of little tourist interest and a petroleum storage plant; sensitive area 2 between Punta Azul and 16°s along 24 km of coast with a first degree upwelling zone; and sensitive area 3 between Cerro Azul and the Concordia Landmark, incorporating 2 petroleum treatment plants.

The Paracas National Reserve is classified as a high priority protection area. It is located in the provinces of Pisco and Ica, and contains 217,594 ha in the sea. It covers three different types of biological communities, but does not have any attractive or distinctive fauna (UNEP/CPPS, 1987f).

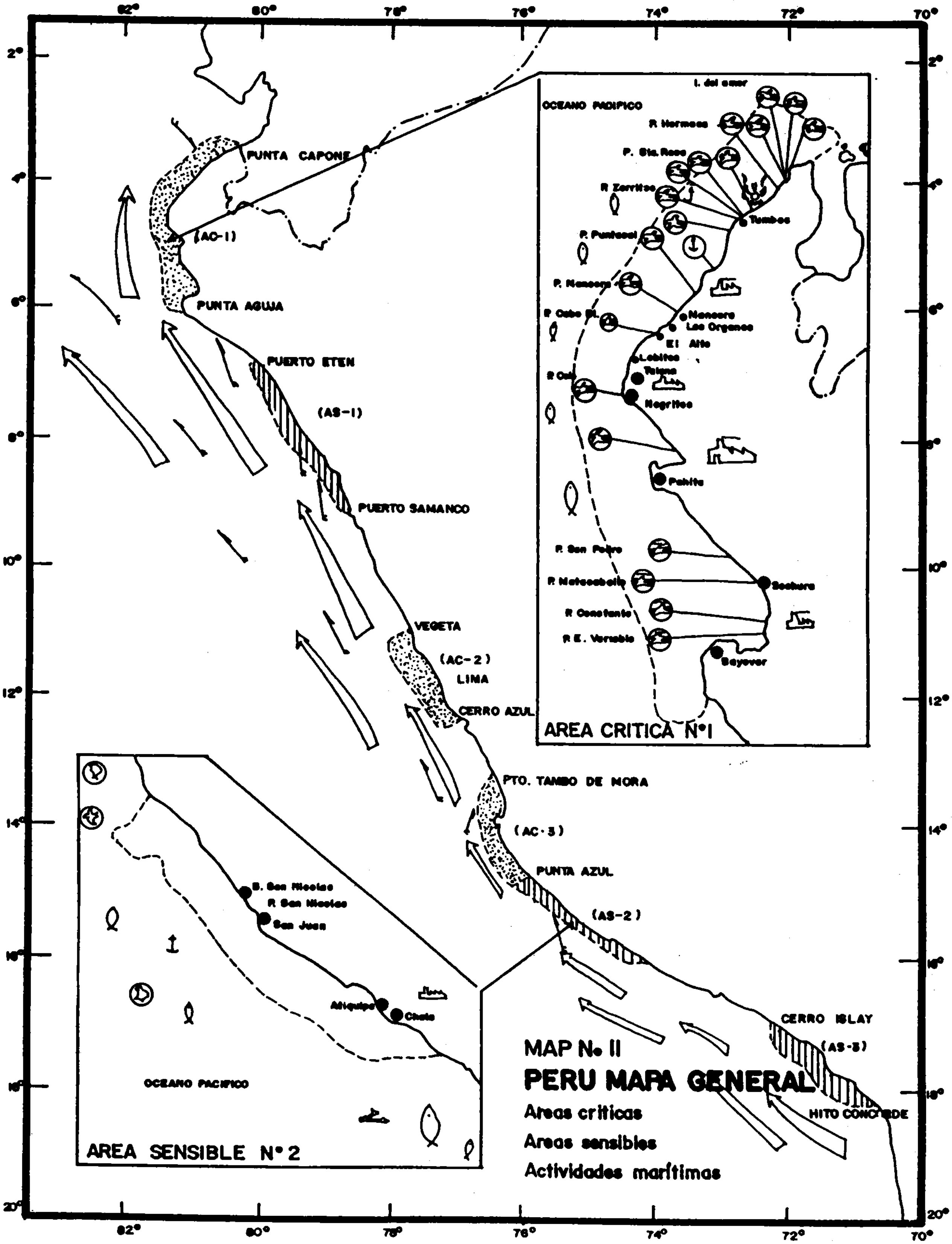
Map 9: Republic of Panama - zones 1 and 4, showing maritime activities



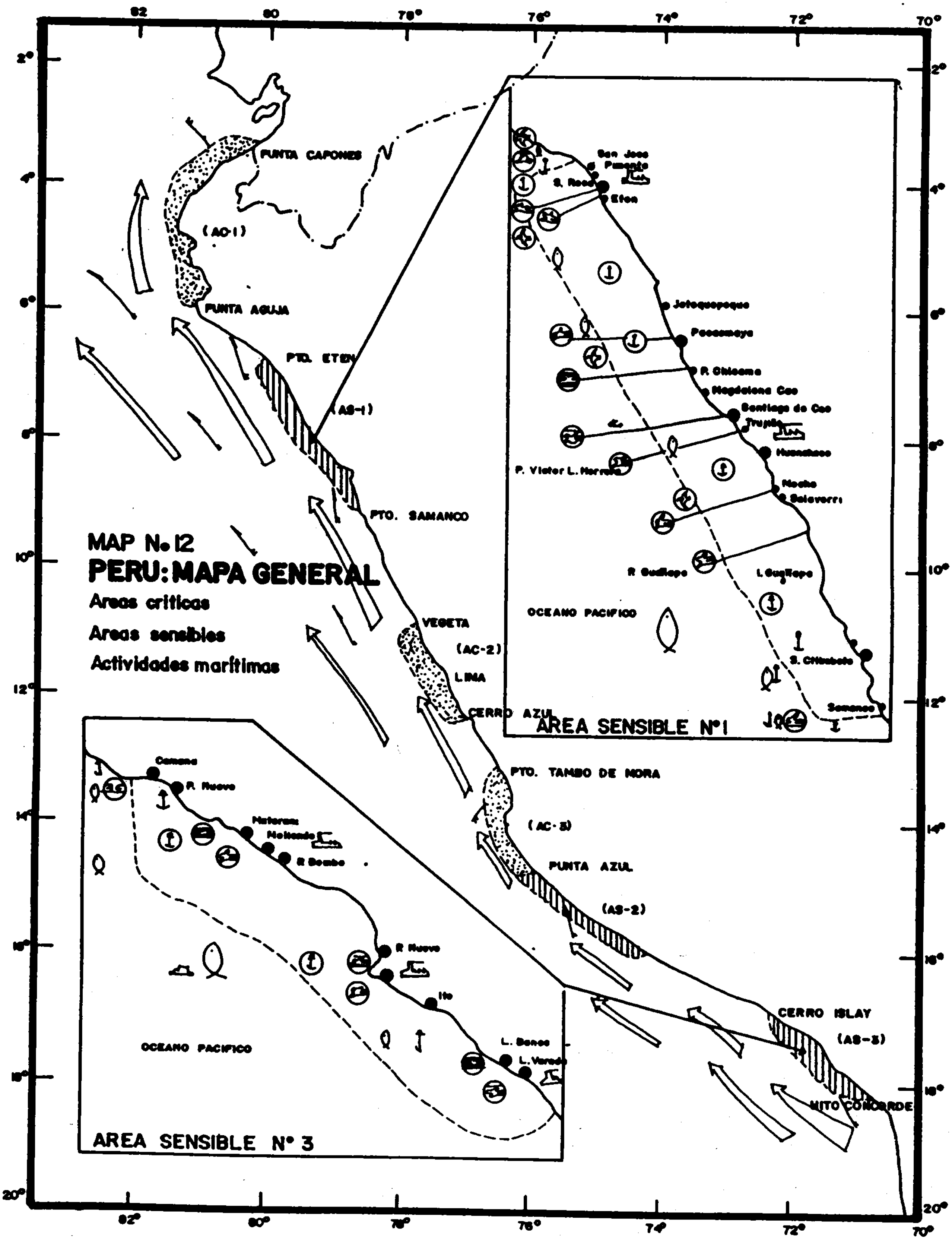
Map 10: Republic of Panama - zones 2 and 3, showing maritime activities



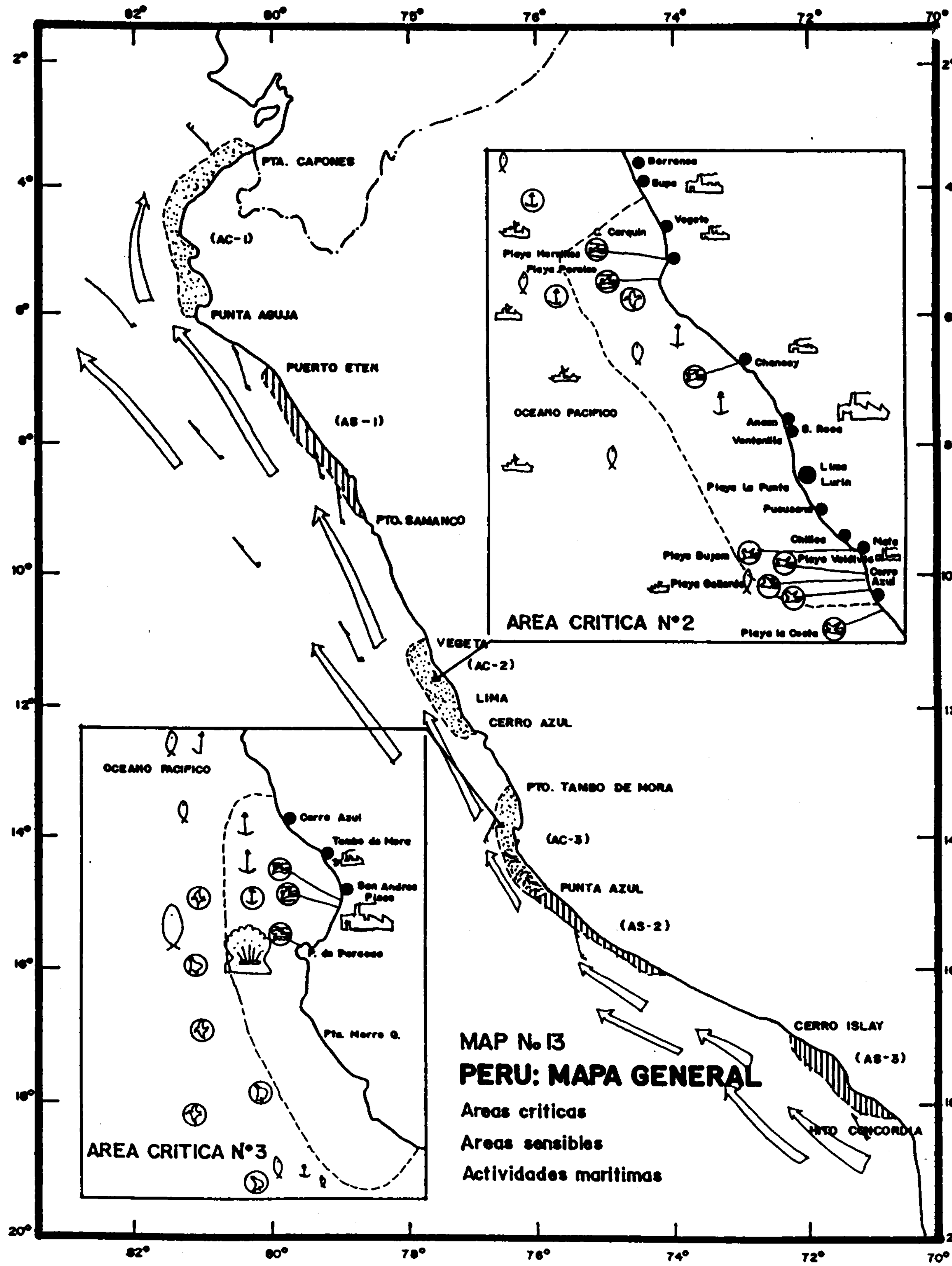
Map 11: Peru - critical area 1 and sensitive area 2, showing maritime activities



Map 12: Peru - sensitive areas 1 and 3, showing maritime activities



Map 13: Peru - critical areas 2 and 3, showing maritime activities



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ACHIEVEMENTS OF THE SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME

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ABSTRACT

To achieve any commendable success in a region encompassing 22 island states and territories sprawled across 29 million km^2 of ocean area will indeed be a major achievement. The Action Plan for Managing the Natural Resources and Environment of the South Pacific Region set the scene for a comprehensive environmental programme for the region and has, as its principal objective, "helping the countries of the South Pacific to maintain and improve their shared environment and to enhance their capacity to provide a present and future resource base to support the needs and maintain the quality of life of the people". The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region adopted by a Plenipotentiary Conference held in Noumea, New Caledonia, from 24 to 25 November 1986, will provide the legal framework for the implementation of the Action Plan. These two instruments will continue to contribute to raising the awareness of environmental problems in the region and to meeting them through co-operative action. Although the full realization of these objectives is still some distance away, the fact that the South Pacific Regional Environment Programme has already gained a high degree of support and co-operation from its island states as well as metropolitan countries such as France and the United States of America is considered a major step towards achieving a healthy environment for the region.

Background

Concern for environmental protection and conservation of the natural resources of tl Pacific has been voiced over a period of more than a decade. Increases in population ai demands upon limited land resources, development of industries, mining activities, the testii of nuclear devices and the proposed use of the Pacific Ocean for disposal of radioacti wastes, have stimulated concerted efforts, on a national and regional level, to protect tl Pacific environment and conserve natural resources through planned development for tl present and future advancement of the Pacific people.

Under the auspices of the South Pacific Commission (SPC), the growing concern f environmental issues has been brought to a wider regional forum, with attention focussed n only on nuclear issues, but also on the erosion and degradation of the environment and tl depletion of rare and fragile species. In 1971, a Regional Symposium on the Conservation Nature - Reefs and Lagoons was organized by the SPC and the International Union f Conservation of Nature and Natural Resources (IUCN). This was followed in 1974 by anoth SPC-initiated project on Conservation of Nature and the appointment of a Region Ecological Adviser. Consultations with the United Nations Environment Programme (UNEP) 1975 led to the development of a comprehensive programme for environmental manageme and proposals for a Regional Conference on the Human Environment. In 1976, the Sou Pacific Forum, the political association of independent Pacific countries, decided that i Secretariat, the South Pacific Bureau for Economic Co-operation (SPEC) should consult wi SPC with a view to preparing proposals for a co-ordinated regional approach to the probler of environmental management, and to develop a comprehensive environmental programr reflecting the interests of all countries in the region.

Also in June 1976, following World Environment Day, a regional meeting on the Convention on the Conservation of Nature in the South Pacific was held in Western Samoa under the joint sponsorship of SPC and IUCN. This regional meeting and the Convention signed there followed up the 1971 Regional Symposium on Conservation and IUCN initiatives based on similar work in other parts of the world. The meeting was the first major attempt in the Pacific to bring about a regional approach, through a legal framework, for co-operative efforts on environmental matters.

The 34th Session of the Economic and Social Commission for Asia and the Pacific (ESCAP), in 1978, endorsed the idea of convening a South Pacific Conference on the Human Environment and recommended that it be held in co-ordination with SPEC and SPC. Proposals submitted to the South Pacific Forum and the South Pacific Conference in the same year led to the subsequent inception of the South Pacific Regional Environment Programme (SPREP), and the organization of the Conference on the Human Environment in the South Pacific which took place in Rarotonga, Cook Islands in 1982. The early development of SPREP has been summarized by Dahl (1985a).

The South Pacific Regional Environment Programme (SPREP)

SPREP is an SPC-executed programme based in Noumea, New Caledonia. It receives directions from its Co-ordinating Group which includes SPC, SPEC, UNEP and ESCAP. From 1982 to September 1986, there was no good mechanism for government officials to be actively involved in deciding on the priorities of SPREP - which was a weakness in the programme structure.

The preparatory phase of SPREP began in 1980 with the writing of country reports and reviews of important environmental topics, which provided an indication of government priorities and of the state of the environment in the region. These reports and reviews led to the adoption of the SPREP Action Plan by the Conference on the Human Environment in the South Pacific in 1982, ten years after the Stockholm Conference on the Human Environment.

The term "South Pacific" as used in the context of SPREP is perhaps misleading as the area covered by the Programme extends right through Melanesia and Polynesia and northward through the islands of Micronesia which lie north of the Equator (Map 1). SPREP is by far the largest Regional Seas Programme in area (29 million km^2) although its total land area is only about 551,000 km^2, of which Papua New Guinea makes up 84 per cent. There are roughly 5 million inhabitants of the region with about 3 million living in Papua New Guinea.

The SPREP Action Plan

The SPREP Action Plan has, as its principal objective, "helping the countries of the South Pacific to maintain and improve their shared environment and to enhance their capacity to provide a present and future resource base to support the needs and maintain the quality of life of the people." Its more specific objectives include:

(1) Further assessment of the state of the environment in the region including the impact of man's activities on land, fresh water, reefs and ocean, the effects of these on the quality of man's environment, and the human conditions which have led to these impacts.

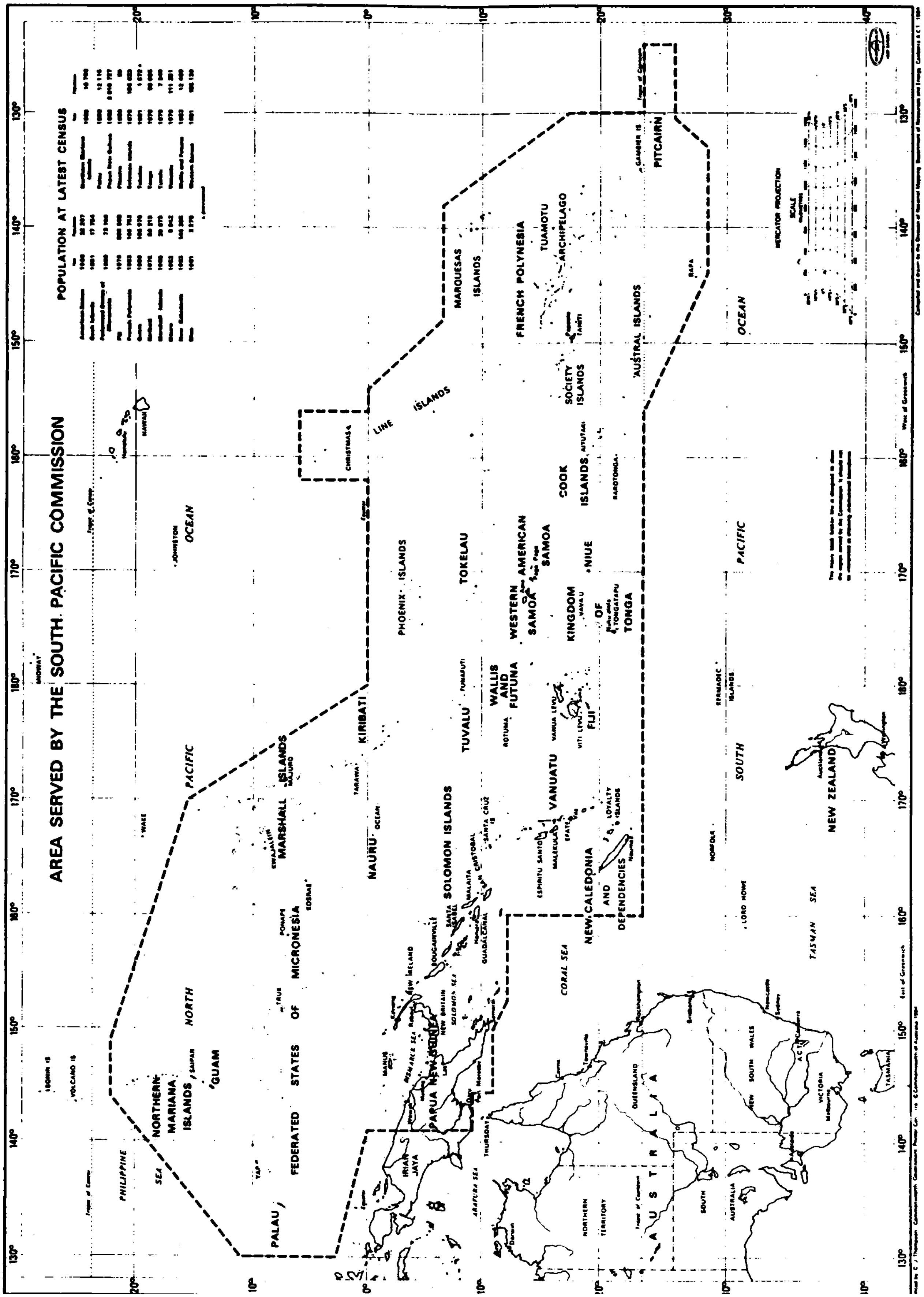
(2) The development of management methods suited to the environment of the region which will maintain or enhance environmental quality while utilizing resources on a sustained yield basis.

(3) The improvement of national legislation and the development of regional agreements to provide for responsible and effective management of the environment.

(4) The strengthening of the national and regional capabilities, institutional arrangements and financial support which will enable the Action Plan to be put into effect efficiently and economically (SPREP, 1982).

The SPREP Action Plan serves as a regional conservation strategy and provides a framework for environmentally sound planning and management suited to the region.

Map 1: Area of the South Pacific Regional Environment Programme



The SPREP work programme elements

Prior to 1986, five main elements had been initiated through the Research and Monitoring Network (a network of national and regional institutions) co-operating in implementing the SPREP work programme. These include studies in watershed management, inland and coastal water quality monitoring and control, survey and monitoring of coastal ecosystems, oceanography, and the regulation of pesticide uses.

In September 1986, environmental officials from 22 member states and territories of SPREP became involved for the first time in deciding on a work programme for SPREP. Subsequently, nine programme elements were identified for inclusion in the 1987-88 work programme. They include regional, subregional and national project activities on natural resource management, protected areas and species, coastal and marine activities, water quality, water management and pollution control, environmental education, information, planning and management, and workshops and training courses.

As an SPC programme, SPREP undertakes activities in response to specific requests for assistance from its member governments or in order to expand the programme to meet other objectives of the Action Plan. In this respect, the field of protected areas and conservation is of particular importance. At the Third South Pacific National Parks and Reserves Conference held in Western Samoa in 1985, the following goals were set for the countries and territories of the region (SPC, 1985):

(a) the establishment of at least one protected area in each country and territory of the region;

(b) an increase to 40 per cent in the number of ecosystems receiving some kind of protection; and

(c) the establishment of 50 new protected areas in the region.

Ambitious as they might seem, the above goals are within the reach of the countries and territories of the region. However, continuing support and encouragement from SPREP and other international bodies will be required if such targets are to be achieved in the next decade.

Support for the SPREP work programme

The SPREP Action Plan has four main chapters dealing with environmental assessment, management, legislation, and institutional and financial arrangements.

In formulating the latter chapter concerning institutional and financial arrangements, the governments outlined the general principles to be followed, and the structures to be established to oversee the implementation of the Action Plan. The governments agreed that "...the ultimate aim should be to make the regional programme self-supporting and as part of the normal programme of co-operative regional activities which would incorporate the SPREP objective..." (SPREP, 1982).

The activities arising from the Action Plan have been financed principally by UNEP under the Regional Seas Programme and through annual voluntary contributions from the member governments of SPREP. Contributions from other international organizations which are not part of the U.N. system (e.g. IUCN, WWF), in most cases on a project funding basis, have also been received for specific projects implemented within the framework of the programme.

In common with other inter-governmental programmes of developing countries, SPREP is often handicapped by financial constraints. The support of UNEP and other international bodies will therefore continue to be needed in the future.

Some major achievements of SPREP

Weighed against its meagre financial resources, one could justifiably say that SPREP has made very impressive progress since the commencement of its implementation phase in 1982. The Action Plan paved the way for concerted follow-up actions at both the national and regional levels and has brought together the countries of the region in an expression of regional solidarity to co-operate in ensuring a healthy and clean environment for the people of the South Pacific.

A regional convention

In 1982, a technical group of international experts was established to review radioactivity and its impact in the South Pacific region. This project was motivated largely by the concern expressed in the region over existing and proposed activities that might release radioactive materials to the environment. Of particular concern were the nuclear explosions being conducted in Polynesia and proposals to include the Pacific Ocean in strategies for radioactive waste management (SPC/SPEC/ESCAP/UNEP, 1983). A similar review was undertaken on the disposal of hazardous wastes in the Pacific Ocean (SPC/SPEC/ESCAP/UNEP, 1984). These reviews were commissioned in order to facilitate negotiations on a regional legal agreement to protect the natural resources and environment of the South Pacific region. In addition, conscious of the fact that regional policies on such difficult issues as the explosion of nuclear devices and the disposal of hazardous wastes could only be implemented through international and regional agreements, SPREP encouraged its member governments to become parties to the London Dumping Convention (LDC) and organized a series of meetings of legal experts to draft a Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (the SPREP Convention). This Convention, with its two specific protocols concerning (i) co-operation in combating oil pollution emergencies, and (ii) prevention of pollution of the South Pacific region by dumping, was finally adopted by a Conference of Plenipotentiaries held in Noumea, New Caledonia, in November 1986. The SPREP Convention was signed by seven countries including France and the United States of America on 25 November 1986 and will enter into force when ten countries have ratified it.

The objective of the SPREP Convention is to protect the natural resources of the South Pacific region, thus aiming for recognition as a regional agreement under Article VIII of the LDC. The SPREP Convention broadly makes provisions for preventing, reducing and controlling pollution from vessels, land-based sources, sea bed activities, atmospheric sources, dumping and storage of toxic and hazardous wastes, and testing of nuclear devices, as well as environmental damage caused by mining and coastal erosion. There is also provision for co-operative efforts to combat pollution in cases of emergency, including a duty to develop and promote contingency plans and to notify other countries if they are likely to be affected by pollution. Because of the unique nature of the Pacific Islands, the Convention also makes provision for appropriate measures to be taken to protect and preserve rare and fragile ecosystems as well as the habitat of depleted flora and fauna. It further creates a general duty to co-operate among the Contracting Parties and with other organizations to share and exchange scientific and technological data, to co-operate with global and regional organizations in the provision of technical and other assistance, and to develop monitoring and research programmes.

The broad scope of the SPREP Convention will give the Contracting Parties greater access to global, regional and sub-regional organizations to assist with the development of techniques, guidelines and legislation, to facilitate balanced development of their natural resources, and to benefit further from scientific research and monitoring programmes, to name a few. Equally important, the Convention, once it enters into force, will provide the legal footing for the operation and implementation of the SPREP work programme.

Action Strategy for Protected Areas

During the Third South Pacific National Parks and Reserves Conference held in Apia, Western Samoa, in 1985, an Action Strategy for Protected Areas in the South Pacific was adopted by a Ministerial Meeting which followed the technical sessions of the Conference. The Action Strategy aims to provide a work programme to implement the conservation and protected area objectives of the SPREP Action Plan. It was developed by field managers from 20 countries during the technical sessions of the Conference. The strategy was thus designed by and for the countries of the South Pacific region, and spells out both general guidelines for action and some specific requirements for most of the member countries of SPREP. It sets out to achieve an increase in the number of protected areas as well as the number of ecosystems receiving some degree of protection in the region.

The five main goals incorporated in the Action Strategy are concerned with conservation education, conservation policy, the establishment and management of protected areas, and regional and international co-operation. The activities identified under each goal are to be initiated at national, regional and international levels, thus broadening the scope of protective measures and environmental management within the region. By 1985, there were 95 protected areas in the region totalling approximately 800 km^2. However, this represents only about 0.15% of the total land area and there is an urgent need for expansion of the protected area network (Dahl, 1985b). The Strategy was therefore based on the premise that further establishment of protected areas was vital to the South Pacific region, because they assist in the maintenance of traditional customs and cultures, help to maintain the main life support systems, contribute to the maintenance of island biological diversity, support research and education, and provide economic opportunities through recreation and tourism (SPC, 1985). In adopting the Strategy, the Conference also endorsed (through a resolution) its implementation within the framework of SPREP.

Although these instruments were promoted and adopted separately, both the SPREP Convention and the Action Strategy aim to achieve regional solidarity in the effective pooling and sharing of resources through co-operative efforts to bring about a strong network of environmental management and protective measures in the Pacific region. This, to a large extent, has been successfully achieved and will provide the basis for further forward progress for SPREP.

Co-operative institutions

As part of SPREP's mandate to seek co-operation from universities and other research institutions within the region, such institutions have been encouraged to undertake an impressive number of projects identified within the Action Plan, with project funds provided by UNEP as part of its support to SPREP. Many projects have been undertaken jointly by two or more institutions, such that the increasing number of co-operating institutions form a network interacting with each other as they co-ordinate the various projects. The number of institutions in this co-operative arrangement with SPREP has increased steadily since the beginning of such arrangements in 1983, and several more institutions are expected to become involved as members of the Association of South Pacific Environmental Institutions (ASPEI) recently established to support the implementation of the SPREP work programme. Appendix 1 provides a summary of some of the major projects undertaken within the framework of the SPREP Action Plan.

Conclusions

The assessment of SPREP in this paper is very general, and at best only covers the relatively recent developments of significance to the programme. How one should view and measure the success of a regional programme such as SPREP in terms of its benefits to the widely dispersed island countries in the South Pacific would require subjective interpretation and is therefore not considered here. Nevertheless, it is clear that SPREP has been effective as a vehicle to enable the island countries to pool and share their resources through co-operative efforts and to bring about a strong environmental awareness in the Pacific region.

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APPENDIX 1: Some Major Projects in Implementation of the SPREP Action Plan

Project title	Implementing Agency	Funding Agency
Watut Divide ecosystem watershed afforestation project	UNITECH	SPREP/UNEP
Hydrologic and nutrient cycling in the Masi and Vatuma catchments, Nadi forest, Fiji	UOG/USP	SPREP/UNEP
Drinking water quality	USP/UPNG	SPREP/UNEP
Heavy metal monitoring in PNG rivers related to mining	UNITECH	SPREP/UNEP
Limnology of Monasavu Dam, Fiji	USP	FEA
Groundwater quality of some atolls of the Tuamotu Archipelago	LESE/ORSTOM	SPREP/UNEP
Monitoring of the Vitogo River area and the associated bay area	USP	SPREP/UNEP
Monitoring of the coastal waters of Guam	GEPA	SPREP/UNEP
Monitoring of the coastal waters of French Polynesia	LESE	SPREP/UNEP
Control of sewage treatment plant effluents in Northern District of Guam	GEPA	SPREP/UNEP
Environmental quality of Huon Gulf, PNG	UPNG	SPREP/UNEP
Use of bio-indicators to monitor chemical and biological contamination in coastal zones	(being developed)	
Pacific lagoon study	USP	SPREP/UNEP
Ecological interactions among tropical coastal ecosystems	UOG	SPREP/UNEP
Oceanography	ORSTOM	SPREP/UNEP
Occupational and environmental hazards of pesticide use	UPNG/USP/ GEPA/LESE	SPREP/UNEP
Pacific resource and environmental data system	UPNG	SPREP/UNEP
Forest inventory in PNG, Vanuatu and Solomon Islands	UNITECH	SPREP/UNEP/ GOVCAN
Melanesian Environment Foundation: community education	UPNG/MEF	SPREP/UNEP
Preparation of regional report on state of marine environment	USP/UOG/UPNG/ LESE/SPREP	SPREP/UNEP
Case studies on environmental issues	ORSTOM	SPREP/UNEP
Review of international and regional environmental conventions relevant to South Pacific region	SPREP	SPREP/UNEP
Preparation of coastal resources data maps	SPREP	SPREP/UNEP
Survey of bird conservation needs in the South Pacific region	SPREP	SPREP/UNEP
Review of hazardous waste disposal and storage in the South Pacific	SPREP	SPREP/UNEP
Review of radioactivity in the South Pacific	SPREP	SPREP/UNEP
Curriculum development for training on rural environmental resource management and development	SPREP	SPREP
Examination of pesticide legislation, storage and handling procedures in the South Pacific region	UPNG	SPREP
Radio project to encourage incorporation of environmental content in radio broadcasting	SPREP	SPREP
Noro cannery field study on potential effects of effluent (Solomon Is.)	CCOP/SOPAC	SPREP/UNEP/ CCOP/SOPAC
Hydrological studies on Port Vila Harbour	CCOP/SOPAC	SPREP/UNEP/ CCOP/SOPAC
Assessment of sewage outfalls in Cook Islands and Western Samoa	CCOP/SOPAC	SPREP/UNEP/ CCOP/SOPAC
Investigation of surface pollution due to suspected natural petroleum seepage in Kiribati	CCOP/SOPAC	SPREP/UNEP/ CCOP/SOPAC
Customary land tenure, conservation and protected areas in the South Pacific	UPNG	SPREP
Pollution sources survey in Tonga	SPREP	SPREP/UNEP
Survey of black coral resources in Tonga	SPREP	SPREP/UNEP
Environmental education in the Solomon Islands	SPREP	SPREP
Production of environmental education material for radio project and ETI network: 5 fact sheets on forests, coral reefs, pesticides, soil erosion and nature conservation	SPREP	SPREP
Training course in practical procedures for project evaluation for coastal zone management, Saipan	SPREP	SPREP
Cook Islands natural history project	SPREP	SPREP/UNEP

ABBREVIATIONS USED IN APPENDIX 1

CCOP/SOPAC	= Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas, Suva, Fiji
FEA	= Fiji Electricity Authority
FMMC	= Fiji Mangrove Management Committee
GEPA	= Guam Environment Protection Agency
GOVCAN	= Government of Canada
ICBP	= International Council for Bird Preservation, Cambridge, England
LESE	= Laboratoire d'Etude et de Surveillance de l'Environnement, French Polynesia
MEF	= Melanesian Environment Foundation, Papua New Guinea
ORSTOM	= Institut Francais de Recherche Scientifique pour le Developpement en Cooperation, Noumea, New Caledonia and Papeete, French Polynesia
SPREP	= South Pacific Regional Environment Programme, Noumea, New Caledonia
UNEP	= United Nations Environment Programme, Nairobi, Kenya
UNITECH	= Papua New Guinea University of Technology, Lae
UOG	= University of Guam
UPNG	= University of Papua New Guinea
USP	= University of the South Pacific, Suva, Fiji

WATERSHED RESEARCH IN THE SOUTH PACIFIC ISLANDS

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ABSTRACT

Measurement of the changes in water quality and quantity in a watershed system is a useful tool for understanding the impacts of development on ecosystems. A major focus of the South Pacific Regional Environment Programme (SPREP) watershed management project is the impact of Pinus caribaea afforestation on grassland hydrology and nutrient cycling in Fiji and Papua New Guinea.

In 1983, two adjacent 450 ha catchments, located on the leeward side of Viti Levu, Fiji, were equipped with automatic rain gauges, weirs, and stage recorders. One catchment is almost entirely in grass. The other, because of hurricane damage in 1983 and 1985, was replanted with pines in 1985. Similarly, three adjacent catchments in the Bulolo-Watut region of Morobe Province, Papua New Guinea were selected for experimentation, and will be equipped with instruments in 1987. Both studies will be conducted for more than 20 years. The results should provide a quantitative basis for evaluating the effects of planting and harvesting Pinus caribaea on the soils, vegetation and hydrology of tropical Pacific Island catchments, so that rational management decisions can be made.

This paper presents the significance, goals, objectives, problems, and work done to date for SPREP-sponsored research activity in watershed management for the South Pacific region. Other watershed management research activities in the South Pacific region will be discussed.

Introduction

In March 1982, the delegates to the Conference on the Human Environment in the South Pacific endorsed the South Pacific Regional Environment Programme (SPREP) Action Plan (SPREP, 1982). The Action Plan, which provides a framework for environmentally sound planning and management suitable to the region (see SPREP, 1984), was based on country reviews and an overall assessment of the Pacific environment and its problems, including the concern over the impacts of development on the natural and cultural resources of the region, the impact of population growth on resources (Dahl and Baumgart, 1982), and the need for the island states to enhance their own environmental capabilities (SPREP, 1982). The following year, the First Consultative Meeting of Research and Training Institutions in the South Pacific Region (Suva, Fiji, April 1983) established both a Research and Monitoring Network, and an Environmental Education and Training Network, each with specific tasks and rôles in order to deal with the complex of environmental assessments and needs. For the Research and Monitoring Network, seven project areas were identified, including watershed ecosystems, because of the close interaction between terrestrial and aquatic systems. Islands such as those in the South Pacific can be considered one system; what happens upstream will affect ecological structure and function in the coastal and marine environment. Each of the projects selected was initiated with a review of existing knowledge to identify a programme of appropriate work activities.

This paper documents the activities of SPREP-sponsored research in the Watershed Ecosystem Management Review Project and the Watershed Management Project, and reviews their significance, goals, objectives and problems. In particular, it focusses on the research activities of two comparable watershed projects, one in Fiji and the other in Papua New

Guinea, where grassland watersheds are being afforested with Pinus caribaea. Furthermore, it suggests that regional co-operation in watershed research is required in order to develop and maintain sound systems of land use, given the many problems present in the region.

Watershed management review project

Large scale development projects, such as mining, tourism and forestry, can greatly affect ecological processes and the sustainability of ecological systems to support life. Underlying premises of the SPREP watershed projects are that assessment of the impacts of land use changes or developments in the Pacific region is necessary in order to ensure that the viability of ecological systems is not impaired, and that any changes in land use will be reflected in changes in the quality and quantity of stream flow. These concerns prompted the delegates at the First Consultative Meeting to recommend that the PNG University of Technology (UOT) prepare, in co-operation with other institutions, a report to:

a) review the extent of mining, forestry and agricultural activities which result in significant physical and chemical soil erosion, sediment transport and deposition;

b) identify the major areas of human-induced sediment deposition in the region; and

c) present in 1984-85 a programme for research to monitor increased erosional and sedimentary problems associated with mining, forestry and agricultural activities within the region (SPREP, 1983).

At the Second Consultative Meeting of Research and Training Institutions in the South Pacific Region (Port Moresby, Papua New Guinea, 1984), it was reported that this review was being divided into three sections: a) terrestrial and fresh-water aspects, b) coastal and estuarine aspects, and c) a bibliography. This division was proposed to accommodate not only mining, subsistence agriculture and forestry activities which have significant impacts on erosion and sedimentation in watershed systems, but also large scale coastal developments such as port construction, fish canneries and tourist facilities which are major sources of coastal erosion, turbidity and sedimentation. The UOT initiated a computer search for general papers on watershed theory, methodology, studies on watershed ecosystems in the region, and legislation in order to ascertain the extent of watershed knowledge and research in the region.

To date the review project is incomplete owing to delays in funding (SPREP, 1984) and the mobile nature of the personnel involved (two of the contributors are no longer with UOT). An additional cause for delay may be inadequacies in the data banks; many of the important papers on watershed research in the Pacific Islands may not be listed in data banks. The review is scheduled for completion in August 1987 (SPREP, 1986).

SPREP watershed management project: background

The underlying purpose of the SPREP watershed management projects is to assess the impacts of Pinus caribaea on the grasslands of Fiji and Papua New Guinea using the approach of Bormann and Likens (1967), Bormann et al. (1967, 1969) and Likens et al. (1977). Basically their method involved the long-term monitoring and analysis of water quantity and quality in small comparative watersheds (catchments). The underlying basis of this approach is that biogeochemical cycles and many ecological processes are closely linked to the hydrological cycle. Thus any change to an ecosystem will be reflected in resultant changes in a watershed's quantity and quality of stream flow. This approach requires the involvement of many specialists in the analysis of a wide range of parameters over a lengthy time period: precipitation and its chemistry; stream flow quantity and quality; soil chemical and physical properties; vegetation composition, biomass and nutrient content; to name but a few.

Afforestation of tropical grasslands is often perceived as an improvement of the habitat as it provides a number of direct and indirect benefits. On Mindanao, for example, Kellman (1969) has shown that surface runoff as a percentage of precipitation is lowest under primary forest, and highest under a 12 year old swidden and grasslands. Logged-over forests have higher surface runoff than tree fallows. Cochrane (1969) reported that 60 to 70% of rainfall in Fijian grasslands was lost as surface runoff in contrast to 5 to 10% from Pinus elliotii plantations in Fiji. Cochrane (1969) also stated that the rates of infiltration, in inches per hour, were from "0.5-1.5 for eroded mission grass areas, 2.0 for dense mission grass-guava scrub, 2.2-2.5 for young pine plantation and over 5 for undisturbed forest." On the other hand, soil degradation resulting from pine afforestation has been documented in the tropics. Tosin (1977) for example, has documented the adverse effects of Pinus elliotii on soil fertility in Brazil. In the Congo, the planting of various pine species in savannas resulted in lower soil organic matter, a more acidic soil, and lower base saturation (Jamet, 1975). Similar results have been reported by Conforth (1970) in Trinidad where P. caribaea plantations were established in cleared areas of natural forest. The harvesting of the trees also reduces the nutrient content of an ecosystem and results in a net loss of macronutrients from the watershed (Ovington, 1965). As nutrient cycling is more rapid in the tropics (Ricklefs, 1979), it may combine with rapid litter breakdown, the release of organic acids, and the loss of nutrients due to harvesting, to produce more rapid soil degradation under tropical conditions than in temperate regions of the world.

In temperate forest ecosystems, comparison of soils under spruce and broadleaf stands indicated that the former showed increased acidity, the accumulation of surficial raw humus, increased compaction and the formation of ortsteins or conglomerates, and decreased macropore space and soluble nutrients. Ovington (1968) notes that the accumulation of mor (an acidic organic layer) under conifers effectively removes nutrients from cycling, and as pines tend to produce mor, it has been implied that these species are responsible for soil deterioration by decreasing the nutrient status of soils. Although this question still needs to be investigated further, decreases in productivity for conifers have been reported by Pelisek (1975). While this research method has been successfully applied in temperate forest ecosystems, few if any researchers have attempted this dynamic approach to studies of land management in the tropics.

The western sides of Viti Levu and Vanua Levu, the two largest islands of Fiji, are dominated by grasslands. Large areas of Papua New Guinea are vegetated by grasslands of presumed anthropogenic origin. Fire and shifting cultivation are often considered to have led to these grasslands. The soils are often eroded, shallow and characterized by poor fertility and structure. Twyford and Wright (1965) have stated that these grasslands are anthropogenic in origin, although this viewpoint has been questioned by Latham (1983b) who compared soil properties under Fijian grassland and Pinus caribaea plantations developed in grasslands. Latham (1983a) found that:

> Ten years after planting, it seems that the pines have not had much influence on the soils of Fiji. The impact is confined to the upper humiferous horizon and chiefly affects physical (bulk density, porosity, structural instability), chemical (carbon, exchangeable calcium and magnesium) and biological characteristics (total biological activity of the soil). For the moment, and in contrast to most of the evidence from other regions, the pines are having a beneficial effect on the soil.

Furthermore, Latham (1983a) noted lower bulk density and structural instability, and higher porosity and moisture retention in the upper horizons of soils under P. caribaea than under grassland. Infiltration rates were at least four times higher under pine than under grassland such that:

> ...the enhanced infiltration capacity of the soils produced under pines will greatly reduce sheetwash and gullying on hillsides, and will regulate stream flow more evenly, with possible water supply and agricultural benefits (Bayliss-Smith, 1983).

However evidence from other parts of the world has shown that afforestation drastically affects ground water and stream flow regimes, particularly in semi-arid environments. Banks and Kromhout (1983) showed that in South Africa's Jonkershoek catchment there were decreased stream flows beginning with the fourth year after planting up until the twelfth year, when a sclerophyllus scrub was replaced by Pinus radiata. Similarly, Van Lill et al. (1980) found decreases in stream flow when Transvaal grasslands were afforested with Eucalyptus grandis and Pinus patula. Hamilton and King's (1983) review indicated decreases in ground- and well-water levels in Australia, Thailand and the U.S. during the dry season when catchment areas were afforested. Simply stated, there is more than substantial evidence that grasslands yield substantially more water than pine plantations and that cutting of the forest canopy reduces evapotranspiration and moisture interception, and results in greater throughfall and higher soil moisture storage, ground water and stream flow levels. Bosch and Hewlett (1982) have predicted that a 10% reduction in coniferous and eucalypt covers will result in a 40 mm increase in water yield

On the drier western sides of Viti Levu and Vanua Levu, more than 30,000 ha of grasslands have been planted with Pinus caribaea by the Fiji Pine Commission. The total area under pines is expected to exceed 60,000 ha. However, the development of this industry is not without hydrological effects. Kammer and Raj (1979) found that low stream flows were reduced by 50% in a watershed that was afforested with 10 year old pines over 60% of its area. The correlation of lowered stream flows and growing pines has been noticed by the residents of the area, many of whom are sugar cane farmers. However, because of the shortness of stream discharge records and the occurrence of drought, a quantitative assessment of the impact of P. caribaea on stream flows has been difficult.

The SPREP watershed project in Fiji

The SPREP-sponsored Fiji watershed management study is located on the western side of Viti Levu on native land leased to the Fiji Pine Commission. The study was initiated in 1981 as a co-operative research project between the University of the South Pacific, the Fiji Pine Commission, and the Hydrology Section of the Fiji Department of Public Works in order to assess the impacts of P. caribaea on the hydrology and nutrient cycling of grassland ecosystems (Manner, 1981). The study is centred on the catchments of Masi Creek and Vatuma Creek. Each catchment is approximately 450 ha in area and similar in geology, climate and topography. Rainfall measured at nearby Nadi Airport averages 1880 mm per annum (Fiji Meteorological Service, 1980). Both catchments have an elevational range between 200 and 400 m above sea level.

The Masi Creek catchment is almost entirely in grassland, with Pennisetum polystachyon and Miscanthus floridulus the dominant graminoid species. Less than 10% of the area was planted to pines in 1980. The Vatuma Creek catchment was almost entirely planted with P. caribaea in 1980. Although every effort was made to locate two adjacent catchments which were completely free of pines in order to ascertain whether or not the catchments were hydrologically comparable, logistical reasons and the scarcity of suitable representative sites made it impossible to find the ideal situation. However, in March 1983, Hurricane Oscar devastated the 1980 plantings in the experimental catchments to the extent that "...most of the areas in this category have been designated for complete clearance and replanting" (Fiji Pine Commission, 1984).

Both sites have been instrumented with combination weirs, stage recorders and automatic rainfall recording gauges. Stream flow records are available from Vatuma Creek since October 1982 and from Masi Creek since September 1983. Rainfall records are available from Vatuma Creek and Masi Creek since October 1983.

Since the start of the project, a wide range of data have been collected. More than 40 stream water samples have been analyzed for pH, conductivity, turbidity, total P, total S and N, Ca, Na, K, Mg, total dissolved solids, Si, total Fe and total Mn. When these data are combined with the stream flow volumes, they will give an estimate of the total export of elements from the two catchments. As the study is to be carried out over a number of rotation cycles, each 17+ years in length, the effects of logging on water quality and quantity will also be determined.

The two catchments have been carefully sampled for soils. Twenty nine soil profiles have been dug for soil characterization studies. These soils have been analyzed for all parameters required for classification according to Soil Taxonomy. The dominant soils have been classified as Ustropepts, Dystropepts and Haplustolls (Manner et al., 1985). A preliminary soil map has been made of the study areas based on aerial photo analysis and field checks. In addition, composite soil samples (0-15 cm) from all major soils have been taken and will be compared to samples taken in the future in order to determine the effects of P. caribaea on soil chemistry. More than 50 calibrated erosion stakes have been established in order to determine erosion under differing conditions of slope, soils and vegetation.

Studies on vegetation composition and biomass have been completed. More than 130 2m x 2m quadrats located in each major soil type have been analyzed for species composition using the Braun-Blanquet cover-abundance method. More than 60 biomass quadrats, each measuring 2m x 2m, have been measured, and productivity studies in each major soil type are currently underway. For the productivity studies, 2m x 2m quadrats are clipped of their vegetation over a fixed growth period and weighed. For tree biomass determinations, 18 P.

caribaea trees have been cut, weighed and subjected to allometric regression analysis. The results of this study have been published (Claeson et al., 1984). More than 30 plant tissue samples have been analyzed for macro- and micro-nutrients, and when combined with the biomass data, they will give an estimate of the nutrients contained in the vegetation.

In addition, these catchments will be analyzed over time for evaporation and other climatic parameters, precipitation chemistry, litter fall, and leaching in soils, to name a few. Because of the variability in soils, micro-catchment studies of soil-plant interactions may also prove valuable.

Since its designation as a research site by the Fiji Pine Commission, the Masi and Vatuma catchments have had a number of problems. Although Hurricane Oscar in 1983 was a methodological blessing in disguise, the project has been hampered by slumping and heavy siltation of the creeks, rendering the stage recorders inoperative by clogging and burying the inlet pipes. At Masi Creek, stream gauging was halted between June 24-August 9, 1982, and February 15-April 5, 1983. At Vatuma Creek, stream gauging also was halted between February 15-April 5, 1983. The problem was solved partially by resiting the inlet pipes. While heavy rainfalls have contributed to slumping and siltation, roading on steep and unstable slopes also seems to be a factor. Finally, destruction and theft of the instruments is an ongoing problem, perhaps because of the sites' isolated locations. For example, in July 1987, parts of the stage recorder at Masi Creek were stolen. The Fiji Pine Commission will be visiting villages in the area in an effort to educate the villagers as to the importance of the equipment to the project's success.

In 1986, SPREP support for the Fijian watershed study was obtained in order to conduct and support further work on soils, stream water chemistry, biomass and plant composition analyses.

SPREP watershed study in Papua New Guinea

In 1984, at the Second Consultative Meeting of Research and Training Institutions (Port Moresby), a watershed management project modeled on the Fijian study was proposed by the Papua New Guinea University of Technology (UOT). The purposes of the Papua New Guinea study were essentially the same as the Fijian study: "to study the impact of Pinus caribaea plantation on hydrological and nutrient cycling in the Bulolo area of Papua New Guinea" (SPREP, 1984). By using a similar model, the UOT study will allow for greater comparability of information between the Fijian and Papua New Guinean contexts.

The Papua New Guinea watershed management project is located in the Bulolo-Watut region of Morobe Province at 800-900 m elevation. It is sited on tribal land centred on Slate Creek. Three adjacent grassland catchments ranging in area between 0.42 and 0.71 km^2 were selected for monitoring in 1984. Mean annual rainfall for the area is fairly low, averaging 1544 mm per annum at Bulolo, and highly variable (Standen, n.d.). The slopes in the area are fairly steep, often in excess of 30 degrees, and often burned.

In 1985, baseflows were measured and peak flows estimated in two of the three catchments in order "to determine the most appropriate flume design and the necessary gearing ratios for water level recorders", the necessary equipment and instrumentation (Ternan, 1985). These have been ordered, but not yet received and installed. On the other hand, analysis of the physical characteristics of the catchments has proceeded very well. Projects already completed include the production of a microtopographical map and a geomorphological survey (SPREP, 1986). Thirty-three soil pits have been dug, and the soils analyzed using a Lamotte Greenhouse Test Outfit (Natera, 1987), and a vegetation survey and classification has been completed.

Since its inception, the Papua New Guinea project has been aided by SPREP-sponsored discussions with the principals of the two watershed studies, and through on-site visits to the Masi and Vatuma catchments. In 1984, the principal investigator of the Fijian watershed study visited Papua New Guinea in order to assess and advise on initial site selection.

Another significant aspect of the Papua New Guinea study is the co-operation of the native land owners. The Bulolo-Watut catchments are located on native-owned lands. Through the efforts of the Senior Forestry Officer at Bulolo, the project has received the support and protection of the villagers in the area. Donald (a local politician) and Baua (the "papa bilong graun") have greatly assisted by informing the villagers about the project and its objectives (Natera, 1987). This co-operation may be critical to the success of the project as grassland fires are annual occurrences and equipment tampering a possibility.

Conclusions

These studies are important from a number of perspectives. Firstly, they will provide baseline data and a better understanding of ecological interactions in tropical grassland ecosystems, and the impacts of afforestation on the hydrology and cycling of nutrients in these systems, so that ecologically and economically rational land management decisions can be made. From an applied perspective, these projects will document the effects of pine afforestation on these areas and more specifically, answer the question whether or not afforesting the grasslands with Pinus caribaea results in decreased steam flows. The economic, political and management implications of decreased stream flows are obvious. The studies of soils and productivity will be useful for site indexing, and should help determine whether or not pines have a degrading effect, so that management decisions can be made to prevent soil degradation and the subsequent decline in pine productivity. The need for such integrated and long-term studies has been stated by Ovington (1968):

> "Many diverse ecosystem processes are concerned in the circulation of chemical elements which is essentially of a polycyclic nature with both long- and short-term cycles being involved. In order to examine more closely the variety of factors affecting the changing distribution of nutrients within ecosystems there is a need for integrated and quantitative studies. The importance of quantitative experimental studies of the nutrient status of soils must be particularly emphasized. This type of ecosystem research may prove to be very important in fulfilling the material requirements of a growing world population."

Perhaps of equal significance to the South Pacific region is the development of local research capacity and expertise through the involvement and training of nationals of the region, a SPREP objective. In early 1985, Mr. Gerard Natera, a Papua New Guinea national, was selected as the research assistant for the Bulolo-Watut watershed project. With SPREP sponsorship, Mr. Natera spent six months at the University of the South Pacific (USP) and the Fiji Pine Commission where he underwent further training in soils, vegetation analysis, and catchment studies. Mr. Natera is currently completing his M. Phil. thesis in Forestry based on his work in the Bulolo-Watut catchments, and will in almost all likelihood, continue working on the project after his graduation. In Fiji, the Masi and Vatuma catchments will serve as a field research site for Mr. Maika Vuki, a Ph.D. student in soils at USP. In the past, the USP Geography Department has used these catchments for field camps in biogeographic field methods.

Finally, these studies may shed some light on the origin of tropical grasslands, a subject of inquiry which to date lacks conclusions. Although human-caused disturbance, primarily through fire and the destruction of forests by shifting cultivation, has been suggested as the origin of tropical grasslands, proof of this is difficult to come by. Climatic and edaphic causes have also been postulated as grassland origins. If the unforested grassland watersheds are protected from fire, and forest succession occurs, I would suggest that these grasslands are indeed anthropogenic in origin. Such protection is possible under the experimental conditions described previously.

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THE POTENTIAL FOR HEAVY METAL POLLUTION TO THE FLY RIVER OF PAPUA NEW GUINEA AS A RESULT OF MINING OPERATIONS

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ABSTRACT

The Fly River is a major waterway navigable by small ships from the Gulf of Papua to Kiunga, a distance of 850 river kilometres. The potential for heavy metal pollution arises from the operations of Ok Tedi Mining Ltd. and the proposed Porgera Gold Mine. This paper looks at the significance of heavy metal pollution in relation to other contaminants. It reviews current and proposed pollution control procedures, and brings into perspective the effluent discharges and the assimilation capacity of a mighty river system.

Introduction

The Fly River originates in the remote west of Papua New Guinea and flows over 1000 km to the south and south-east to a large delta in the Gulf of Papua. Along the way it picks up major tributaries in the Ok Tedi and Strickland rivers. The relationship of these rivers is shown in Figures 1 and 2.

Figure 1: General location of the Fly River

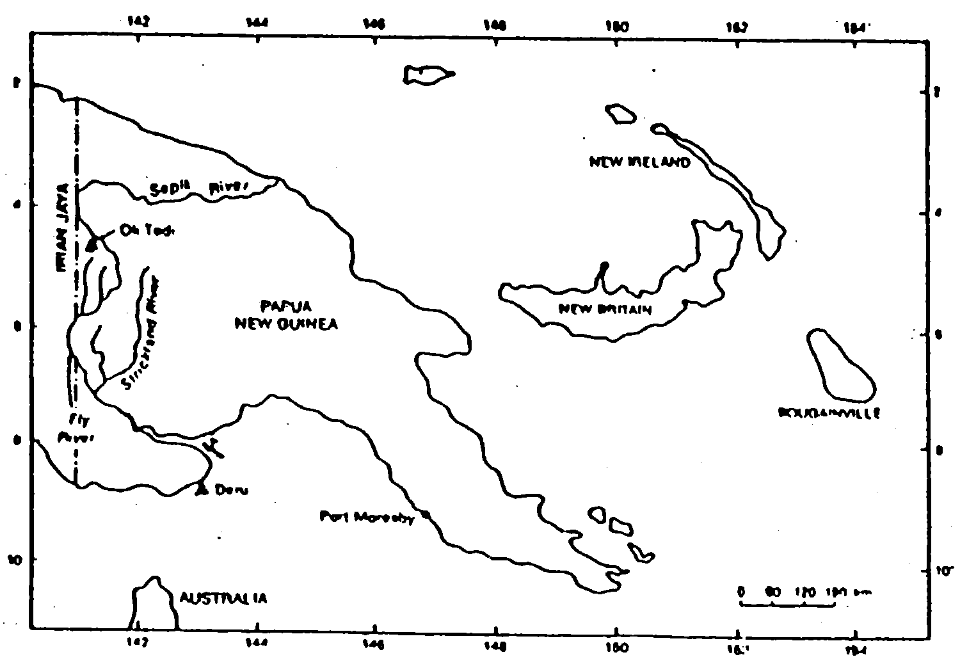
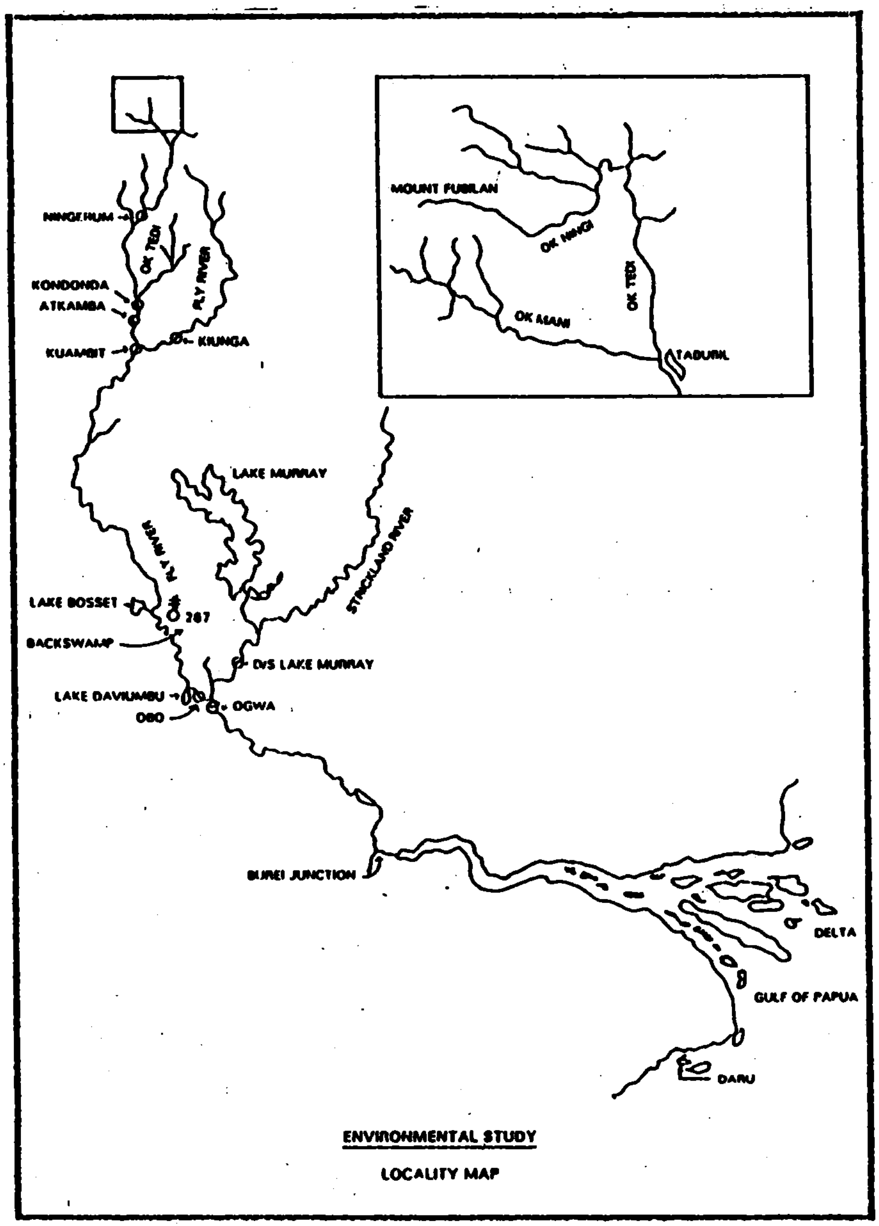


Figure 2: Locality map - OTML environmental study



Rainfall in the catchments is extremely high. At Tabubil, the Ok Tedi Mining Ltd. (OTML) mine town, the mean annual rainfall exceeds 8000 mm (315 inches) per year. The average decreases to 3000 mm (118 inches) near the coast (Eagle and Higgins, 1987). The Ok Tedi joins the Fly River 220 km downstream of the mine site, whilst the Fly-Strickland confluence is approximately 355 river kilometres from the Gulf. The Fly River has an estimated mean annual discharge in excess of 6000 cubic metres per second, and a natural sediment load estimated at between 80-100 million tonnes (Mt) per year.

Mt. Fubilan, site of the Ok Tedi Mine, is located in the Star Mountains of Western Province. Construction activities for OTML commenced in 1981. Gold production began in May 1984, whilst the first copper processing facilities were commissioned in May 1987. The initial rich leached-ore gold cap of Mt. Fubilan has nearly been worked out and gold production will probably cease within twelve months. In the period May 1984-December 1986, 12.3 Mt of waste rock and 14.1 Mt of tailings had entered the Ok Tedi River and 20 Mt had reached the middle Fly. Of this 20 Mt, 5.9 Mt was from waste rock, which means 6.4 Mt of waste rock is stored along the length of the Ok Tedi River. The material reaching the middle Fly has resulted in a median suspended sediment concentration increase of 65 mg per litre at Kuambit.

The Porgera gold/silver deposit is located in the Central Highlands Province of Enga. The processing of the ore will end with a cyanide leach, carbon-in-pulp (CIP) recovery, with discharge of tailings to the river system - the Porgera, Lagaip, Strickland, and ultimately the Fly River. Over the projected 18 year lifetime of the mine, only 47.6 Mt of ore will be processed (Rescan Environmental Services, 1987), a small operation compared with OTML's revised maximum of 25 Mt per year.

Present beneficial uses of the river system

In the Porgera area human use of the river system includes gold panning in several rivers in the area of the proposed mine site, some subsistence fishing, and clothes washing. No organized use of the rivers for drinking purposes has been identified (Rescan Environmental Services, 1987). Below the confluence of the Pongema and Porgera Rivers, there appears to be almost no human use of the mainstream of the system until below the Strickland gorge in the upper flood plain. All of the villages along the Lagaip and Strickland Rivers in the mountain region have little contact with these rivers. In the flood plain region, the numbers of people are small but the reliance on the Strickland and Fly River resources increases. Fish from the rivers and tributaries are a significant component of the diet. In the Lake Murray, Lower Fly and delta areas, commercial fishing is important.

In the Ok Tedi region, an abundance of side streams makes the use of the river for drinking purposes unnecessary, whilst very little subsistence fishing occurs. Two commercial fisheries operate in the middle Fly, at Lake Bosset and Obo (Applied Geology Associates, 1987). The target species is barramundi. The main obstacle to increasing the catch appears to be motivation of the fishermen, but if this was to change, the size of the operation could grow quickly, possibly to the point where the barramundi population becomes the limiting factor. Apart from subsistence and commercial fishing, a major use of the Fly River is for transport.

Natural characteristics of the river system

The predominant climatological feature of the region is rainfall, and at both Tabubil and Porgera precipitation occurs on over 300 days each year. Porgera is not as wet as Tabubil, receiving about 3600 mm (142 inches) compared with Tabubil's 8000 mm.

Weathering processes have produced a fine soft soil surface in much of the catchment area. The extremely high rainfall in the catchments produces fast-flowing, high-gradient creeks, streams and rivers laden with eroded suspended solids. These support minimal aquatic life and are of minor importance to the inhabitants. The Porgera River, initially at an elevation of about 1700 m, flows into the Lagaip which joins the Strickland at an elevation of about 520 m. The steep descent continues until the vast floodplain is reached. From the confluence of the Nomad and Strickland Rivers in the mid-region of the upper floodplain, it is over 700 km to the Gulf but the elevation change is only about 100 m. The floodplain is extremely flat and the river gradients slow slight that the Fly and Strickland Rivers flow in meandering fashion creating extensive back swamps.

Contaminants arising from the mining operations

For both the OTML and Porgera operations, the categories of contaminants released to the river system are the same: solids, cyanides, and heavy metals. Production of gold through a cyanide leach process will cease at OTML within the next twelve months and therefore this contaminant will no longer be discharged there. Because the gold was associated with a porphyry copper deposit, large amounts of copper entered the Ok Tedi River system as the dicyanocuprate ion. Other metals in the Mt. Fubilan ore body include arsenic, cobalt, iron, manganese, lead, molybdenum and zinc. The Porgera Gold Mine effluent discharge should be consistent over the lifetime of the mine, with the environmentally significant metals including iron, arsenic, nickel, copper and zinc.

The Ok Tedi operation

In the original scheme of things, OTML was to discharge tailings into a permanent tailings dam constructed in the Ok Ma Valley. Nature intervened when a massive landslip buried the partially constructed dam. The Government of Papua New Guinea subsequently approved an Interim Tailings System (ITS). The ITS included detoxification of cyanide by chemical treatment with hydrogen peroxide, hydrocycloning of tailings to separate a coarse fraction from the fines, deposition of the coarse fraction (up to 25% of daily production) behind a dam adjacent to the process plant, and discharge of fine tailings direct to the Ok Mani and thence to the Ok Tedi. Waste rock generated by mining of the ore body is eroded from waste dumps and eventually finds its way to the Ok Gilor, thence to the Ok Ningi and Ok Tedi.

The initial compliance point for the monitoring of free cyanide and total dissolved copper was at the Lower Ok Tedi Bridge just outside the township of Tabubil. A dilution factor of 2.5 was applied for comparison with data obtained at Ningerum. On 15 July 1985, compliance monitoring was shifted to Ningerum. This was tantamount to sacrificing over 70 km of the Ok Tedi River to be used as a waste disposal drain. The free cyanide criterion was initially set at 5 ppb, then raised to 30 ppb at Ningerum when the company consistently failed to meet the criterion. The total dissolved copper (TDC) level of 50 ppb could not be met either, in spite of the very generous allowance of a 70 km mixing and dilution zone. Problems in the control of plant processes, variations in the composition of the ore, and/or low flow conditions in the river were responsible for excesses. The company engaged overseas experts to provide arguments to be presented to the Government for relaxation of the criteria. Usually the Government (Department of Minerals and Energy) was very slow to respond, presumably because of difficulty it experienced in assessing the validity of arguments put to it by OTML. Invariably the company got away with exceeding the water quality criteria or obtained relief by the raising of the acceptable limit. Given that the Ok Tedi had been deemed to be of no beneficial or environmental significance, such decisions or lack of decisions were probably realistic. Free cyanide does not present a long-term problem as it undergoes rapid natural degradation, as do the less stable of the metallocyanides.

Cyanide is instrumental in keeping copper in solution. High TDC values considerably in excess of the official present 50 ppb limit have been common. For instance, in the period January-May 1987, 35% of 908 TDC analyses exceeded 100 ppb and 10% exceeded 200 ppb (Gawne, 1987). Whilst such figures highlight the difficulty OTML has experienced in controlling copper inputs to the river, they need to be put into perspective. The highest TDC ever recorded at Ningerum, 1269 ppb, only resulted in a TDC of 16 ppb at Kuambit, which is immediately downstream of the confluence of the Ok Tedi and the Fly River.

The Sixth Supplemental Agreement

On 28 February 1986, a new agreement was reached between the Government, OTML and the company's shareholders. Called the Sixth Supplemental Agreement, it provides for:

a) increased gold process throughput to 30,000 tonnes/day;
b) early construction of copper processing facilities with progressive increase of throughput to 70,000 tonnes/day by the end of 1988;
c) deferral of construction of a permanent tailings disposal system until 1990;
d) a total quantity of 100 Mt of waste rock to pass into the Fly River, measured at the confluence with the Ok Tedi, up to 1 January 1990;
e) an Environmental Study to be undertaken by OTML over the period 1986-1989.

The Environmental Study will concentrate on "the river system" defined as "the Fly River below the confluence of the Ok Tedi with the Fly, down to and including the delta" (OTML, 1986).

The agreement required OTML to review all effluent and monitoring data collected since January 1981 within the six month period ending December 31, 1986. The report (OTML, 1987) submitted in January 1987 was praised by Applied Geology Associates Ltd. (1987), consultants for the Department of Minerals and Energy, who wrote: "The overriding impression is the high quality of the work undertaken by the OTML staff, and the comprehensive reporting completed to date." In addition to the report (OTML, 1987), the biological sampling (Hortle, 1986) and hydrologic data (Paige and Eagle, 1986). Yet another consultant, TAMS Consultants Inc. (1986), stated : "The amount of hydrologic data already available...is very extensive. It appears that these data would be sufficient for the monitoring and modelling purposes outlined in the Sixth Supplemental Agreement." "The...OTML water quality sampling effort is extensive and has resulted in a large accumulation of analytical data." "Given its location, the OTML Environmental Laboratory has excellent analytical capabilities and equipment."

Some pertinent findings of the reviews include:

1) A comparison of 1981-1986 data indicates that significant changes have occurred in suspended sediment, particulate copper, dissolved copper, particulate zinc and dissolved manganese concentrations in the Ok Tedi. Particulate zinc had returned to background level at Kuambit, but the others remained elevated above baseline concentrations.

2) 13,000 analyses of cyanide and TDC at Ningerum showed significant increases in free cyanide and dicyanocuprate ion levels. The dicyanocuprate undergoes considerable dissociation during passage to Kuambit. No other dissolved metal concentrations have increased as a result of cyanide releases into the Ok Tedi River.

3) An index, derived by dividing the average ore body concentrations by the average concentrations associated with suspended solids measured at Ningerum, assumed that the dominant form of transportation of the metals was the particulate phase. The potential for enhancement over background is indicated if the index is greater than unity. Only three metals, Cu, Fe and Mn, had indexes greater that one.

4) 30,000 fish were collected from nine sites over three years. Trace metal concentrations were determined in over 5000 specimens. The abundance of some species and the total standing crop in the Ok Tedi have been reduced, but a few species very tolerant of turbid water have increased in abundance.

5) Despite mine inputs, the composition of the fauna at Ningerum and below remains similar to that of large tributary streams. Effects on the fauna do not appear to have extended further downstream than the Ok Tedi/Fly River junction.

6) Population fluctuations occur naturally (mainly because of drought) and are large and certainly more severe than any induced by operations of the project.

7) The 100 Mt limit of mine-derived sediment passing to the middle Fly will be reached some time in 1992. The mean level of bed cross section at Konkonda (see Figure 2) has increased by 0.6 m since 1981.

8) The mean daily discharge at Bukrumdaing (upstream of Tububil) is 20 cumecs whilst at Kuambit it is 2000 cumecs.

The main features of the environmental provisions of the Agreement are:

a) the deferral of construction of permanent waste retention facilities until 1990; and

b) the Environmental Study to assess the impact of discharges and thus to determine the extent of permanent facilities necessary to contain environmental impacts at acceptable levels.

The company shall provide to the State the findings of the Environmental Study as soon as practicable after such findings have become available to the company. On the basis of those findings, the State will establish, not later than 1 January 1989, an Acceptable Particulate Level (APL) for suspended solids in the river system resulting from OTML mining operations. The compliance point has yet to be agreed upon. In arriving at the APL, five criteria have been outlined in the Agreement to be given consideration. In the first three the State acknowledges the desire for the project to proceed (the State is a shareholder), that some impact on the environment is unavoidable, that there is presently limited use of the area concerned, but that mining operations should not cause unacceptable environmental damage. It is stated not only that the APL should tend toward the maximum level consistent with avoiding significant damage, but also that the cost of facilities to moderate the impact on the river system that are not necessary for that purpose are unacceptable costs.

Recognition is to be given to a cost/benefit assessment of the facilities necessary to achieve compliance with incremental levels of suspended particulate matter.

The company will propose a strategy to protect the river system, e.g. construct a permanent tailings dam, facilities other than a tailings dam, or no additional facilities. If the State considers the company's proposed strategy to be inadequate to ensure compliance with the APL, the State and the company shall negotiate. If after thirty days no agreement is reached, the matter is to be referred to the environmental expert whose decision is final and binding. The expert must base his determination solely on the results of the environmental study.

The cynical conservationist would have a field day attacking the company and the Government on the matter of environmental protection. Notwithstanding the excellence of the work carried out by the dedicated Environmental Section of OTML, one could highlight:

1) the consistent failure of the company to comply with copper and cyanide standards;
2) the acquiescence of the State in relaxing water quality criteria;
3) the successive shift downstream of the compliance point until the whole 220 km of the Ok Tedi has been given over to the company;
4) the environmental study upon which the APL will be set is being carried out by the company;
5) chemical and metal standards are deemed to have been established and are not subject to revision by the study;
6) the likelihood of protracted argument both over the APL and the location of the compliance point;
7) costs are to assume great importance in the strategy;
8) the expert must base his opinion on figures supplied by the company;
9) the State's desire for the project to be a successful revenue earner.

Some of the above can be countered by reference to reputable consultants who are to make regular reviews of the progress of the environmental study.

The current requirement for solids input into the system is defined in terms of cumulative sediment yield and not in terms of limits on instantaneous loadings and sediment concentrations. This is probably the most realistic approach with respect to monitoring, policing and control, but may not be the most environmentally significant measure for assessing the direct degree of mining-related disturbance to the river system (Applied Geology Associates, 1987). Accurate determination of river flow and sediment transport regime is of fundamental importance in arriving at the APL. Compliance with the present sediment yield requirement could be met either by not releasing more than the imposed limit or by releasing in excess of the limit and relying on Ok Tedi and tributary storage to control the passage of waste into the Fly River. "The Company has opted for the latter approach" (Applied Geology Associates, 1987). By the "dump time" limit (1 January 1990), 131 Mt of rock waste are projected, and thus compliance will need to be met by the storage of 31 Mt upstream of the Ok Tedi/Fly River junction. In arriving at the APL, separate assessments of inputs from tailings, rock waste and natural sources will be required.

During the period of the environmental study, OTML is to determine the biological significance of sediment-associated trace metals to the aquatic fauna resident in the river system. Cu, Fe, As, Mn, Co, Mo, Pb, and Zn occur within the ore body but the majority of these metals are found in the skarns which comprise only 5% of the ore reserves. From the heavy metal standpoint, consultants have drawn attention to copper. Are impacts likely to be caused by remobilization of copper from mine-derived sediment in the river system? How much particulate associated copper will deposit in the Fly River, the delta and the Gulf of Papua? Applied Geology Associates (1987) specifically recommend that the objectives of the water quality programme should be extended to include a mass balance for particulate copper.

During the period of the environmental study, the company is to assess the socio-economic value and extent of commercial and subsistence fisheries activities and other perceived beneficial water uses of the river system, and to evaluate existing cultural values of the resources of the system. Up to January 1987, little progress has been made on this study. Work undertaken to date focusses on the commercial and subsistence value of fishing. There is no report of any work yet on the existing cultural values of the river resource or on perceived beneficial uses other than as a fishery.

<u>The Porgera gold project</u>

The proposed mining operation at Porgera will be on a very much smaller scale than at OTML. The treatment plant will consist of crushing and grinding facilities followed by gravity concentration to recover any free gold. The gravity circuit tailings will then be floated to produce a sulphide concentrate. About 86% of the gold is associated with crystallized pyrite. The concentrate will be pressure oxidized to make it amenable to leaching of the gold and silver by cyanide. The precious-metal-rich cyanide solution will then flow through a carbon-in-pulp circuit to remove gold and silver. The residual cyanide in the tailings will be destroyed, either by chemical treatment or by introduction to the acid neutralization circuit, before discharge to the river system.

Terrain differences profoundly affect the quality of the receiving water environment. The mountain streams are highly turbid and have limited capacity for biological productivity. The lower Strickland and Fly Rivers have reduced turbidity and relatively high productivity, particularly in the adjacent wetlands which are important habitats for a wide diversity of aquatic and terrestrial species. Hydrological records are available for four stream gauging stations operated by the Bureau of Water Resources and Natural Systems Research Consultants. These stations monitor flow at:

- SG1 Porgera River, below the mine site;
- SG2 Lagaip River, immediately below the confluence with the Porgera;
- SG3 Strickland River, upstream of the gorge; and
- SG4 Strickland River, on the upper flood plain about 100 km downstream of the gorge.

There is a high degree of dilution within the Porgera, Lagaip and upper Strickland River system, the mean flow for SG4 being approximately 68 times that for SG1. The variation in flow between the high and low extremes of each station is not exceptionally large (Rescan Environmental Services, 1987). Table 1 gives values for flow rates and suspended solids. The 10% exceedance values mean that flows will be equal to or greater than this value 10% of the time.

Table 1: Flow rates and estimated background concentrations of suspended sediment for the Porgera-Lagaip-Strickland River system (Source: NSR Environmental Consultants)

Stream Gauge Station	Flow (m^3/s)			Suspended solids (mg/l)		
	90%E	Mean	10%E	90%E	Mean	10%E
SG1	6.2	16	28	275	615	995
SG2	70	180	320	165	1185	7885
SG3	319	704	1243	197	1440	6020
SG4	500	1080	1900	77	305	830

Only limited data are available at the present time concerning water quality within the Strickland watershed. The mountain region streams typically have pH 7.7 to 7.9, hardness around 100 mg/l as calcium carbonate, and high suspended solids. The Pongema, Porgera and Lagaip Rivers all contain elevated levels of copper, but these do not persist below SG3. All other dissolved metal values are either negligible or below the limit of analytical detection. The heavy metal content of river bed sediment samples is listed in Table 2. Iron is the most abundant metal present in the sediments, followed by zinc, copper and nickel - all below potential problem levels. The heavy metal content of suspended solids sampled in August 1985 by Rescan Environmental Services (1987) is shown in Table 3. Iron and zinc are once again the predominant metals but the concentrations of most metals were significantly higher in suspended solids than in the sediment.

Table 2: Heavy metal content of stream bed sediments
(µg/g dry weight)

etal	Porgera above Pongema	Pongema above Porgera	Porgera (SG1)	Lagaip (SG2)	Strickland (SG4)	Strickland above Herbert	Lake Murray (Kuskin)	Herbert River A	Herbert River B	Strickland below Herbert
rsenic	4.60	4.90	8.00	7.00	9.25	10.0	2.30	7.50	8.75	14.0
admium	<0.25	<0.25	0.30	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
opper	14.5	16.0	24.0	36.5	24.5	26.0	31.5	20.0	24.5	27.5
on	32300	31500	37250	44300	42200	44150	22850	37800	40400	43700
ead	9.00	7.75	15.5	12.5	13.3	14.5	14.0	11.0	11.8	14.5
ercury	0.020	0.025	0.045	0.040	0.025	0.025	0.015	0.025	0.025	0.045
ickel	16.0	16.0	20.5	33.5	33.0	36.0	22.5	34.0	36.5	52.0
elenium	0.23	0.28	0.29	0.27	0.17	0.22	0.32	0.13	0.17	0.39
inc	73.5	72.3	107	99.0	90.5	95.5	67.0	86.5	86.5	90.0

Table 3: Heavy metal content of suspended solids
(µg/g dry weight)

	Porgera (SG1)	Lagaip (SG2)	Strickland (SG3)
Arsenic	11.9	8.67	12.2
Cadmium	<1.9	1.90	1.98
Copper	25.3	25.5	36.3
Iron	457000		476000
Lead	42.4	24.4	16.5
Mercury	0.15	0.35	0.13
Nickel	19.0	32.5	100
Selenium	<1.9	<0.6	<0.5
Zinc	131	106	112

In the analyses of pilot plant process wastes:

(a) heavy metal concentrations in flotation tailings were sufficiently low that no environmental problems are anticipated;

(b) the slurry discharge from the C-I-P process showed extremely low metal concentrations, except for iron. None of the levels for dissolved metals, including iron, are environmentally significant.

Thus discharge of process wastes from the Porgera Mine should have a significant effect on mountain region rivers only in respect of suspended solids, with dissolved chemical species being so low in concentration as to have no deleterious effects outside of the mixing zone. This assumes that process control will be up to standard. In view of the Ok Tedi experience, one might be forgiven for being sceptical.

The potential for heavy metal pollution of the river system

The discharge of any waste material will impact upon the receiving environment. Therefore a better title for this paper would have been "The potential for unacceptable heavy metal pollution of the river system." The degree of unacceptability will vary according to the nature of the receiving environment, perceived beneficial uses, and the value of the project, i.e. environmental protection is all about realistic compromise.

Given strict policing of the compliance with water quality criteria by the Porgera Gold Mine Project, the reduction in the amount of copper entering the Ok Tedi once gold production ceases at OTML, and acceptance of data produced by the OTML section, one should be able to assert that heavy metal pollution of the river system will be within acceptable limits, and of secondary importance to the impact of suspended solids. Because of the small scale of Porgera in comparison to OTML, the impact of the Porgera operation on the Fly River System should be negligible by comparison. Certainly there does not appear to be any allowance for a Porgera contribution in the terms of reference of the OTML environmental study which will form the basis for setting the acceptable particulate level (APL).

The Fly River System is a mighty river system, 70 m deep at the Fly-Strickland junction. It can assimilate waste at one end, and through processes of attenuation (oxidation, precipitation, dilution, abrasion, adsorption), moderate impacts downstream. Because of the ability of the natural environment to assimilate and degrade contaminants, one can argue that waste disposal is a legitimate use of the environment. In relation to the main contaminant, solid waste, the OTML staff state:

i) that the whole of Mt. Fubilan, some 1000 Mt, if stored in the Fly River System, would only cover the bed to a depth of 0.1 m;

ii) that the delta contains 72,000 Mt of sediment in the top 1 metre which is unstable and constantly shifting. The 22 Mt of tailings waste plus waste rock from the mine can be diluted forever and a day by this constant reworking of the top layer of delta sediment;

iii) the natural sediment load of the Strickland River is 100 Mt/year.

Beyond the delta - international concerns

At the Torres Strait Fisheries Seminar, Port Moresby, February 1985, the following statement was made: "Because the Fly River is the largest and most important freshwater input into the Torres Strait region, the participants of this seminar wish to express serious concern over possible effects that dumping of Ok Tedi mining wastes into the Fly River may have, directly or indirectly, on Torres Strait fisheries."

Japanese interests are developing prawn fisheries in the Gulf. Australian interests, such as the Great Barrier Reef Marine Park Authority, have expressed concern at the possible transport of heavy metals from the Gulf to the northern regions of the Great Barrier Reef.

Conclusion

The potential for pollution of the Fly River System to an unacceptable level by heavy metals as a result of mining operations should be minimal:

GIVEN:
(a) the length of the system;
(b) the huge mean annual discharge;
(c) low concentrations in the ore bodies;

PROVIDED:
(a) compliance with water quality criteria is enforced;
(b) the Acceptable Particulate Level is set conservatively;
(c) the strategy to comply with the APL is realistic.

Will a permanent tailings disposal facility ever be built? At this stage, it would be safe to say this would not be the preferred strategy.

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FISH-TRANSECT SURVEYS TO DETERMINE THE INFLUENCES OF NEIGHBORING HABITATS ON FISH COMMUNITY STRUCTURE IN THE TROPICAL PACIFIC

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ABSTRACT

Fish communities were surveyed by visual counts along 50m transect lines on isolated coral reefs, on coral reefs bordered by seagrass beds, on coral reefs bordered by mangroves, on coral reefs bordered by both seagrass beds and mangroves, and also in seagrass beds and mangroves, each of the latter two in four situations of bordering habitats analogous to the four situations of coral reefs surveyed. Populations of adult fishes differed as a result of habitat characteristics, not because of the influence of neighboring habitats. Populations of juvenile fishes may differ among sites because of influences of neighboring habitats, but differences in juvenile populations were not necessarily carried over into adult populations. Interactions among coastal habitats appear less pronounced in the tropical Pacific than in the Caribbean. Within habitat diversity of coral-reef fish communities may not differ greatly between the Caribbean and the Central Pacific, but between habitat diversity is considerably greater in the Pacific because of the relatively discrete, nonoverlapping nature of fish communities between habitats. The practical implications of these findings are that the Caribbean coral-reef fish communities may be able to recover more easily from catastrophic disturbances or local extinctions through immigration from surrounding habitats. The relatively discrete or segregated nature of fish communities on Central Pacific reefs may result in higher susceptibility of the fish community to local overexploitation or disturbance.

Introduction

There is a wealth of literature documenting the dependency of commercial and recreational marine fisheries on coastal habitats in the tropical Atlantic (Darnell, 1958, 1961, 1967; Skud and Wilson, 1960; Sykes and Funicane, 1966; Smith et al., 1966; Odum and de la Cruz, 1967; Wood et al., 1969; Heald and Odum, 1970; Cronin and Mansueti, 1971; Odum and Heald, 1972; Carr and Adams, 1973; Snedaker and Lugo, 1973). It is generally accepted that 70-90% of commercial and sport fish species depend on coastal habitats for at least part of their life cycle (Adams et al., 1973). Even if coastal habitats are critical for only a small period in the life of an organism, the availability of the habitat is essential for the survival of the population. Neighboring habitats can be important for fishes as nurseries for juveniles, as a source of food for adults and juveniles, and for numerous other benefits. When monetary estimates of mangrove value were made for the west coast of Florida on the basis of the dependence of commercial marine fisheries alone, the wholesale value was $10.4 million in 1971 (Adams et al., 1973). The value would be several times greater if recreational fisheries and secondary economic benefits were also taken into account.

If subsistence and commercial fisheries on tropical Pacific islands are similarly dependent on, or benefit from, interaction between coastal ecosystems, then the estimated value of the marine vascular plant communities (mangroves and seagrass meadows) would be high relative to the total island economy. Coastal marine ecosystems are of particular importance for indigenous peoples of the Pacific Islands. Tropical Pacific Islanders have always depended upon coastal marine resources for at least 90% of their animal protein (Johannes, 1977). The potential yield from artisanal fisheries in coral reefs and lagoons is about the same magnitude as the offshore tuna harvest, at least in Micronesia (Mitchell, 1975; Johannes, 1977). It is essential that we understand the functioning of tropical coastal ecosystems and the interactions between ecosystems in order to develop rational management plans for the small islands.

Coastal ecosystems on oceanic islands not only contain important food products, they also provide great logistic advantages. Therefore human settlements and urban development are also concentrated in coastal regions, especially in harbours and along rivers which drain into nearby coastal areas. As human populations grow on small Pacific oceanic islands or atolls, the coastal habitats become both the areas most essential for obtaining natural resources such as animal protein, and the areas most directly impacted by man's development activities such as land clearing and pollution. This dilemma in the management of coastal ecosystems, in which the value of renewable organic resources must be weighed against economic and logistic development as the human population increases, makes it essential to understand the functioning of coastal ecosystems. In particular, an understanding of how the coastal ecosystems interact with each other and with the abutting terrestrial and offshore areas is of primary importance as a basis on which to make sound rational decisions about development, land use and coastal zone resource management.

The questions

Despite the wealth of literature proclaiming the importance of interactions between neighboring habitats to the marine fish communities, no solid evidence is presented. Indirect evidence is given for two mechanisms by which fish communities are positively affected by neighboring habitats: as sources of additional food for adults, and as nursery areas for enhanced recruitment of juveniles. For example, Randall (1963) and Ogden and Zieman (1977) observed that reefs near seagrass beds supported a larger biomass of reef fishes than did other reefs. They also noted that the increased biomass was made up largely of carnivorous fishes (pomadasyids, haemulids, lutjanids, holocentrids, apogonids, etc.) which exploit seagrass beds for invertebrates and small fishes at night. When Randall (1963) constructed an artificial reef of 800 construction blocks in a seagrass bed, the artificial reef was able to maintain a resident population of reef fishes with eleven times the biomass per unit area of comparable areas of natural fringing reef. Therefore, it might be inferred that the greater biomass of fish foraging out from the coral reef into seagrass meadows is a result of the additional food supply available in seagrass meadows. Coral reefs are characterized ordinarily as closed systems with recycling of nutrients, while seagrass meadows are open export systems.

However, these observations and experimental results do not conclusively support the influence of nutrient transfer because there are alternative explanations. One alternative explanation is the "edge effect". The artificial reef may have been a smaller self-contained entity than the natural reefs. The relative abundance, biomass or diversity of fishes between reefs may be partly a function of the ratio of border length to surface area of each reef. Furthermore, any bordering area between different habitats might have a greater abundance, biomass or diversity of animals than the average patch of either habitat. The observations at habitat borders and the artificial reef experiment provide interesting indications of the importance of nutrient transfer from seagrass beds to coral reefs, but these studies should be repeated more rigorously with controls for patch size and edge effect.

A second possible mechanism by which a fish community can benefit from a neighboring habitat occurs when one habitat serves as the nursery for a species which resides in another habitat as an adult. Ogden and Zieman (1977) stated that seagrass beds serve as nurseries for juvenile Diodon, Holocentrus, Ocyurus, Acanthurus, Mulloidichthys, and Halichoeres which apparently settle from the plankton into seagrass beds, spend time in seagrass beds growing as juveniles, then later take up residence on coral reefs. They report that Diodon juveniles are observed to arrive between June 15 and July 15 each year (for at least 3 years previous to 1977) as dense schools of thousands that presumably settle from the plankton. Gladfelter (in Ogden and Zieman, 1977) says the schools are visible from an airplane as large dark spots.

Snappers (Lutjanidae), grunts (Haemulidae), and the great barracuda (Sphyraena barracuda) initially recruit to seagrass beds and mangroves. Snappers are particularly dependent on mangroves as a nursery. The great barracuda spends its first year in seagrass beds and its second summer among the roots in the mangrove swamp (de Sylva, 1963). It is interesting to note that Sphyraena barracuda and the reef squid Sepioteuthis are circumtropical except for the Pacific coast of the Americas, where seagrass beds are essentially nonexistent in the tropics. Perhaps the absence of S. barracuda and Sepioteuthis is a result of the lack of a suitable nursery.

Seagrass beds and mangroves have also long been recognized as important nursery areas for commercial, sport, and bait fishes and for commercial shrimp and spiny lobster (Kutkuhn, 1966; Clark, 1971; Sastrakusumah, 1971; Young and Kirkman, 1975; Ogden and Gladfelter, 1982). Seagrass beds and mangroves are presumed to serve as nurseries largely because of the shelter provided to small fishes and crustaceans by the extensive field of grass blades or by the complex maze of prop roots. Seagrass beds and mangroves are also richly endowed with a supply of organic detrital materials which serve as a food supply for juveniles. As the fishes and crustaceans grow, hiding in these refuges becomes less effective and so they tend to school and eventually move into their respective adult habitats. As Ogden and Gladfelter (1982) point out, seagrass meadows and mangrove regions are excellent fishing areas for tarpon, snook, and other large predatory fishes which roam the habitats in search of juvenile fishes to eat.

Shulman and Ogden (in press) documented that 95% of Haemulon flavolineatum recruits settled onto the sand and seagrass lagoon floor, later moving to nearby coral reefs, while 5% of the recruits settled directly onto the coral reef. However, they also documented that fewer than 0.08% of the recruits survived one year. Many species of reef fishes are found on isolated reefs and pinnacles, many kilometres from seagrasses, mangroves, or lagoons. If a certain quantity of fishes are able to live on an isolated reef and only 1/1250 (=0.08%) of recruits survive, then it is conceivable that the 5% of H. flavolineatum recruits that settled directly onto the reef were adequate and the majority that settled in neighboring habitats and moved to the reef were superfluous.

So although fishes occasionally appear an order of magnitude more abundant on patch reefs or on the edges of reefs bordering seagrass beds, this may be the result of the "edge effect" or ratio of border length to total area, and although seagrass beds bordering coral reefs may receive up to 95% of the recruits of the region, the remaining 5% that set directly on the reefs may be adequate. Isolated coral reefs are inhabited by large reef-fish communities. Do interactions between tropical coastal marine communities have a significant influence on the ecology of the ecosystem? If these interactions are significant, then they are certainly important for coastal resource management. If a coral reef community next to a mangrove has different attributes than an isolated coral reef community, then questions concerning altering the mangrove (e.g., clear cutting for wood, land-fill for coastal housing, draining and filling for agriculture, etc.) must take this into account.

The two basic questions addressed in this study were:

1. Were the larger biomasses of fishes on reefs bordering seagrass beds a result of concentrations of fishes near borders (an "edge effect"), or a result of the neighboring habitat being a source of additional food supply?

2. Does added recruitment to neighboring habitats which serve as nurseries ultimately add to the standing stock of the reef fish population?

Methods

This study was undertaken in the vicinity of Motupore Island Research Station, southeast of Port Moresby, Papua New Guinea. In order to survey the influence of neighboring habitats on fish community structure objectively, we chose to survey fish communities on coral reefs in four situations (in isolation, bordered by seagrass beds, bordered by mangroves, and bordered by both seagrass beds and mangroves), in seagrass beds in four analogous situations (in isolation, bordered by coral reefs, bordered by mangroves, and bordered by both coral reefs and mangroves), and in mangroves in four analogous situations. We were able to find replicates of all situations except coral with mangrove without seagrass; we only found one such site, and took counts there on three separate days.

The study sites were selected from an Australian Navy Hydrographic Branch chart (number AUS 621). Replicate sites were chosen as far apart as possible so as to determine whether the influence of a neighboring habitat is robust enough to show effects under varying circumstances, i.e., to avoid pseudoreplication (Hurlbert, 1984). Appropriate situations for replicate 50 m transects were found at distances 500 m to 12 km apart. Although pelagic fishes undoubtedly travel these distances, the fishes with which this study is concerned are assumed to have restricted foraging ranges and are not likely to travel so far.

At each replicate site and each habitat, the fish community was surveyed by visual counts along a 50 m transect line. The transect line was laid within the habitat being surveyed, then the observer would swim along the transect line, counting and recording all the fish seen within one metre of either side of the transect line. Each transect count was therefore over an area of 100 m^2. Counts of adults, juveniles and larvae were recorded separately on mylar or underwater paper.

Substratum surface occupied by living coral, various groups of algae (filamentous turf, fleshy macroalgae, crustose corallines), and other categories were measured by randomly tossing a quadrat with 16 intersecting points and tallying the items under each of the 16 points. The quadrat was tossed at least 32 times along each coral reef transect for a total of at least 512 data points for estimating relative surface cover by various categories along each transect.

Results

Fish communities were more densely populated on coral reefs than in mangroves, and more dense in mangroves than in seagrass meadows (Table 1). The numbers of species of fish on an areal basis (per 100 m^2) were also greatest on coral reefs, less in mangroves, and least in seagrass meadows (Table 1). For each of the three habitats (coral reefs, mangroves, seagrass meadows), there were no significant differences, in either population density or number of species, between habitats that were isolated and those that bordered on other habitats. For communities of adult fishes, population density and species richness varied between habitats, but the bordering habitat made no significant difference.

Table 1: Abundance and species number of coral reef fishes in habitats alone and with various combinations of bordering habitats (mean + standard error along 50 m [100 m^2] transects)

	Coral Reef			Seagrass			Mangrove		
	No. Transects	Mean	Standard Error	No. Transects	Mean	Standard Error	No. Transects	Mean	Standard Error
Alone (isolated)	4			4			5		
adults		327	+ 91		9.2	+ 7.0		139	+ 80
juveniles		6.8	+ 3.1		3.0	+ 2.4		65.2	+ 53.2
no. species		24	+ 3.2		2.5	+ 1.5		5.0	+ 0.8
with Coral Reef				5			3		
adults					8.8	+ 8.1		8.0	+ 3.5
juveniles					4.2	+ 3.3		18	+ 8.5
no. species					3.8	+ 1.9		6.0	+ 3.0
with Seagrass	5						5		
adults		264	+ 89					38.6	+ 23.0
juveniles		26.6	+ 13.1					63.8	+ 30.3
no. species		24	+ 1.7					5.2	+ 1.7
with Mangrove	3			4					
adults		404	+ 61		5.0	+ 2.7			
juveniles		23.3	+ 8.3		1.5	+ 1.5			
no. species		31	+ 0.6		1.8	+ 0.75			
with both	4			4			3		
adults		223	+ 74		8.8	+ 3.3		13.3	+ 5.6
juveniles		136	+ 121		1.5	+ 1.2		29	+ 16
no. species		26	+ 3.0		3.2	+ 0.6		6.5	+ 1.4

Juvenile coral reef fishes appeared to recruit 3 to 20 times more abundantly on coral reefs near seagrass and mangroves than near isolated reefs (Table 1), although this trend did not show statistical significance. Conversely, the populations of juvenile fishes in mangroves away from coral reefs appeared to be 2 to 3 times denser than in mangroves near coral reefs (Table 1), again not significant. The greater recruitment to coral reefs bordered by mangroves or seagrasses and the greater recruitment of fishes to mangroves away from coral reefs might suggest that coral reefs are dangerous to larval fishes, perhaps because of abundant planktivorous fishes, and that mangroves might provide refuge among the prop roots. However, no significant negative correlation was found between the population density of adults and juveniles, so this hypothesis was not supported.

For territorial and for schooling herbivorous fishes, there was a positive correlation between herbivorous fish abundance and the proportion of the substratum occupied by filamentous algae. The abundances of territorial and schooling herbivorous fishes were positively correlated with each other, but not significantly. When all the data are included, the association between strongly territorial pomacentrids (*Stegastes* spp. and *Plectroglyphidodon lacrymatus*) and other herbivorous pomacentrids was positive; but when data were used only from the half of the transects which had the most abundant territorial pomacentrids, the correlation was negative.

The population density of coral-eating chaetodontids was positively correlated with the percent cover of living coral ($r=.43$, $p<.05$). The density of juvenile corallivorous chaetodontids did not change among habitats and so, in effect, the proportion of juveniles in the population increased as the percent coral cover decreased (Table 2).

Table 2: Population density and percent juvenile corallivorous chaetodontids

Habitat	Adult population density (no. per 100 m^2 transect)	Percentage of population juvenile
Isolated coral	12.2	8.2%
Alcyonaceans prevalent	6.8	11.8%
Coral near seagrass	6.4	16.%
Coral near mangroves	4.3	7.7%
Coral near both seagrass and mangroves	2.0	25.%
Deep reef (9 m depth)	3.8	26.3%

Chaetodon trifascialis and *C. baronessa* were associated with *Acropora* coral heads. *C. melannotus* was found associated with alcyonacean soft corals. The chaetodontids that fed mainly on invertebrates other than coral, and the fishes that fed on small fishes and motile invertebrates (mullids, apogonids, pomadascyids, lutjanids, *Parupeneus barberinus*, *Thalassoma hardwickii*, etc.), were found widely distributed across all habitats. *Gerres* spp. and *Sphaeramia orbicularis* were found among mangrove prop roots, while *Sphaeramia nematoptera* was found on the forereef slopes of coral reefs. These patterns of distribution were consistent regardless of neighboring habitat.

Discussion

The data from our study indicate that in the vicinity of Motupore Island, Papua New Guinea, it is the nature of the habitat itself that is the major determining factor in the abundance and distribution of the fishes, not the influence of bordering habitats. We found no evidence to support the hypotheses that: 1) a greater biomass of reef fishes is supported on reefs bordering other habitats, or 2) that additional juvenile fishes in neighboring habitats make a significant contribution to the population density of adult reef fishes.

Although the data from our survey were not conclusive, it does appear that the number of juvenile fishes was several times greater on coral reefs near mangroves or seagrass beds than on isolated coral reefs. Conversely, recruitment appeared less in mangroves near coral reefs than in isolated mangroves. Regardless of possible differences in recruitment between areas of a certain habitat bordered by different habitats, the adult populations in a given habitat did not appear to vary in population density or number of species conditions. On a finer scale, adult corallivores varied within a habitat in positive correlation with surface cover of living coral, but the juveniles did not. In all cases, the abundance of adults was not closely correlated with the abundance of juveniles. The distribution of Chaetodon trifascialis and C. baronessa appears associated with Acropora spp., C. melannotus with alcyonaceans, and Sphaeramia nematopterus with forereef slopes, regardless of neighboring habitat.

When data from the entire set of coral reef transects are included in the analysis, the population densities of strongly territorial herbivorous damselfishes are positively correlated with population densities of other herbivorous damselfishes. When the half of the transects in which territorial herbivores are most abundant are analysed by themselves, the other herbivorous damselfishes are negatively associated with territorial damselfishes. This is an interesting example of a problem of scale when sampling. On coral reefs in general, an area that is favourable for one herbivorous species is probably favourable for others. But when the areas in which the territorial herbivorous species are abundant are selected for examination, the correlation is negative, presumably because competitive interactions are effective at this scale of reference. At either scale, no influence of neighboring habitats could be discerned.

The literature documenting interactions among tropical coastal ecosystems is based on studies undertaken in the Caribbean (reviewed in Ogden and Gladfelter, 1982; Birkeland, 1985). The present study was done in the western tropical Pacific, and the results obtained differed from those in the Caribbean. In the Pacific we find much less influence between coastal habitats.

Some Caribbean fishes that feed on small motile invertebrates aggregate during the day on coral reefs in large numbers, often by the hundreds, then move out to forage on seagrass beds at night (Ogden and Ehrlich, 1977; Ogden and Zieman, 1977). In the Indo-West Pacific, some species (perhaps Gnathodentex, Monotaxis, Macolor, apogonids, holocentrids) possibly follow this behavior pattern as individuals or in small groups, but we have not seen this pattern in the Pacific at the same magnitude as in the Caribbean. The Caribbean fishes that forage on seagrass beds return to coral reefs where they defecate during the day, allegedly adding enough nutrients to the water around coral heads where they aggregate to benefit growth of coral colonies (Meyer et al., 1983). This interaction has not been documented on Pacific reefs.

The juveniles of some coral reef fishes such as Chaetodon vagabundus and Parupeneus barberinus were found in neighboring habitats such as mangroves and seagrass meadows. However, fishes such as these which prey upon small motile invertebrates generally have broad habitat distributions and are also found in neighboring habitats as adults. There are numerous cases in which both adults and juveniles are found in more than one habitat, but no cases were noticed in our study in which juveniles and adult fishes occurred in different habitats.

Sale (1980) suggested that within-habitat diversity (Alpha Diversity) of coral reef fishes might not differ greatly between the Caribbean and the Central Pacific, but the between-habitat diversity (Beta Diversity) is substantially greater in the Central Pacific. There is less overlap between habitats among coral reef fishes in the Pacific. The results of our study are consistent with Sale's generalization.

The lesser between-habitat diversity in the Caribbean may have important implications for resource management and coastal development plans. Coral reef fish communities in the Caribbean may be more resilient to catastrophic disturbance or local extinction because of immigration from surrounding habitats. The relatively discrete or segregated nature of fish communities on Central Pacific reefs may result in higher susceptibility of the fish community to local overexploitation or disturbance.

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EQUATORIAL PACIFIC MONITORING

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ABSTRACT

The ORSTOM Centres in Noumea (New Caledonia) and Papeete (French Polynesia) initiated monitoring of the intertropical Pacific Ocean using ships of opportunity. Surface temperature, salinity, chlorophyll, and zooplankton have been routinely measured since 1969 and temperature of the 0-400 m upper layer since 1979, allowing the description of seasonal as well as long term changes in these parameters. Major results concern the "El Nino" event which was shown to affect the whole Pacific Ocean.

In the framework of the TOGA (Tropical Ocean and Global Atmosphere) programme for the decade 1985-1995, this network was enlarged and ORSTOM started in addition a programme consisting of bi-annual cruises along the 165°E meridian from 20°S to 10°N in the western equatorial Pacific. New data sets of current profiles (0-600m) and CT DO_2 hydrological profiles (0-1000m and 0-2000m) were used to improve the knowledge of the western Pacific current system. They also showed up severe limitations in the calculation of dynamic height from XBT and mean T/S curves alone, especially at the equator, because of the large variations below 400m and in the salinity structure. However even at the equator, there is good agreement between the mean geostrophic and the mean directly measured currents.

Introduction

The tropical oceans have a very strong influence on the earth's climate due to their capacity to store heat from the sun and to export it to poleward regions. The Pacific Ocean has the greatest influence because of its size. The westward currents driven by the trade winds in the tropics concentrate much of this heat in the western Pacific. Schematically, the ocean absorbs energy from the atmosphere in the eastern Pacific, whereas energy is transferred from the ocean to the atmosphere in the western Pacific. This exchange occurs mainly close to the Intertropical and the South Pacific Convergence Zones (ITCZ and SPCZ) in the atmosphere, which are areas of strong atmospheric convection. Humid air heated by contact with the ocean rises up into the atmosphere, where the water vapour condenses, releasing latent heat and reinforcing the convective activity.

Up to 1970, oceanographic descriptions of the tropical Pacific Ocean were based exclusively on the results of oceanographic cruises by research vessels. These gave very accurate descriptions of ocean conditions but only for a small zone and for a few weeks. Repeated cruises would have been necessary to follow changes in time and space in the marine environment, but there were neither the funds nor the research vessels and oceanographers to do this.

Between 1970 and 1980, climate research was greatly stimulated by the occurrence of two El Nino events (1972 and 1976) which had large climatic effects on the entire planet, with drought in Australia, the south-west Pacific and the north-east of Brazil, heavy rainfall in the equatorial islands, and a severe winter in the U.S.

The study of the mechanisms of heat transfer is one goal of the TOGA (Tropical Ocean and Global Atmosphere) international programme planned for the decade 1985-1995.

Ships of opportunity network

The need for more oceanographic observations led the ORSTOM Centre in Noumea to search for a simple, economic and very flexible way to obtain data, so it was decided to use the many merchant ships continuously plying the oceans. With some good will on the part of the ship's officers, a great variety of measurements could be made (physical and biological, surface and subsurface) while the ship was underway without the need for scientists on board.

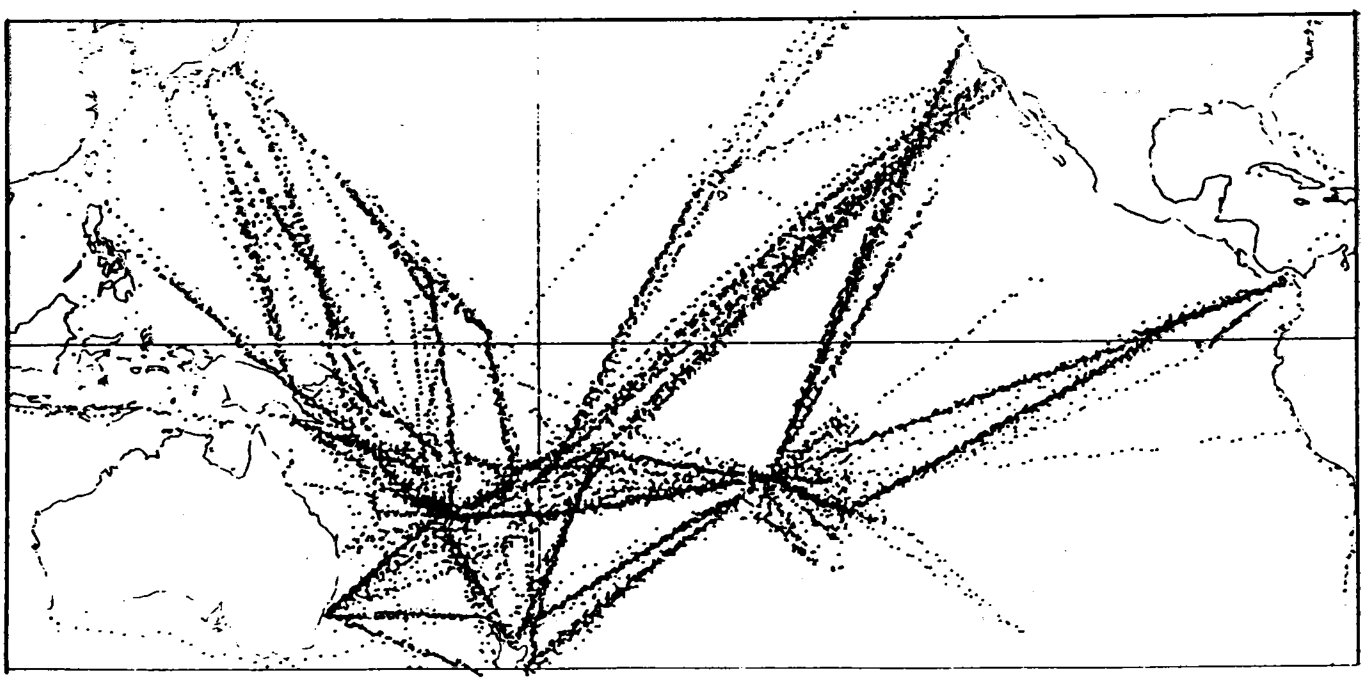
The ORSTOM network started as early as July 1969 when the officers of a Japanese nickel ore carrier were persuaded to aid scientists voluntarily by measuring, free of cost, the sea surface temperature between Japan and New Caledonia, and collecting surface water samples to be analysed for salinity in the ORSTOM laboratory.

The results obtained and the climatic features observed along this western line during the 1972 El Nino phenomenon led to the extension of this observational network to other shipping routes. The ORSTOM Centre in Papeete, French Polynesia, was then included in this programme which is called SURTROPAC (SURvey of the TROpical PACific) and which constitutes a large part of TOGA. The shipping routes used are: Noumea-Hong-Kong, Noumea-Japan, Noumea-California, Noumea-Tahiti-Panama, Noumea-New Zealand, Noumea-Australia, Papeete-Hawaii, Papeete-California, and Papeete-New Zealand. Around Noumea and Papeete, observations are also made by naval vessels and by regional and coastal shipping lines.

Surface observations

Approximately 10,000 surface observations are made every year along the network shown in Figure 1, including meteorological observations, water temperature, salinity, chlorophyll, and on a few lines zooplankton samples.

Figure 1: Network of surface observations using ships of opportunity



Many papers have been published using the data from the surface network, including the description of surface salinity in the tropical Pacific (Donguy and Henin, 1976; Henin and Donguy, 1979), and the relationships between salinity and the surface current system, rainfall patterns and the location of wind convergence zones (Donguy and Henin, 1980).

One of the main results was the description of the year to year variability which was observed, particularly in 1972 and 1976 when the Coral Sea was very salty, the equatorial areas received heavy rainfall, and important eastward surface countercurrents developed. These events were directly related to the El Nino phenomenon which was previously thought to be restricted only to the eastern Pacific, along the coast of South America. It is now clear that it affects the entire tropical Pacific and even higher latitudes (Philander, 1983).

The measurements of surface chlorophyll concentration are of great interest for the prediction of the climatic consequences of accumulating carbon dioxide in the atmosphere because of the close relationship of CO_2 with marine photosynthesis. Carbon dioxide gas dissolved in the ocean is converted to organic carbon and settles down to the sediments at great depths. This process may reduce the excess atmospheric carbon dioxide accumulated through the industrial use of fossil carbon (Dandonneau, 1986). When satellite measurements of chlorophyll become routinely available, our surface observations from ships of opportunity will be useful to calibrate the satellite estimates. During the 1982-83 El Nino event, there was a radical change in the surface chlorophyll concentration (Dandonneau, pers. com.).

Subsurface observations

To monitor the heat content of the ocean, we need subsurface data (Henin and Donguy, 1980), so we have used XBT (Expendable BathyThermograph) probes on the ships of opportunity network since 1979. An agreement between the Scripps Institution of Oceanography in California and the ORSTOM Centre in New Caledonia provided funds for the use of XBT probes giving temperature profiles of the 0-460 m upper layer. A thermistor probe transmits the temperature to the deck through a very light electric wire. The data are recorded on audio cassette tapes using an inexpensive personal computer.

Using mean T/S (temperature/salinity) relationships, the dynamic topography relative to 400 m was computed from 20°N to 20°S along our ship tracks in the western, central and eastern Pacific. The results showed an accumulation of warm water in the western and central Pacific and its release during the 1982-83 El Nino when warm water accumulated in the eastern Pacific. Studies are presently underway to compare the results of numerical models of the wind-driven circulation to the geostrophic currents deduced from the observed temperature structure (Picaut and Tournier, pers. com.). The main difficulty is to obtain a good set of wind data, which is questionable because of the very small number of wind observations made at sea.

SURTROPAC cruises

In addition to surface and subsurface monitoring with the help of ships of opportunity, the SURTROPAC group initiated monitoring of the 10°N-20°S transect along the 165°E meridian with oceanographic cruises by research vessels. Starting in 1984, the R/V Coriolis has made two cruises per year, in January and July, to take very precise measurements of temperature, salinity, dissolved oxygen, chlorophyll and nutrients from the surface to 1000 m and even 2000 m. Direct observations are also made of currents in the 0-600 m layer, and zooplankton samples are collected.

The first three years of observations (1984, 1985 and 1986) allowed us to describe the mean water masses and movements along the 165°E meridian (Delcroix et al., 1987; Delcroix and Henin, 1987). The direct current observations were compared with the geostrophic currents deduced from CTD profiles and from XBT observations. The water transport estimates agree, but the high variability of the equatorial distribution of salinity introduced errors in the dynamic height estimations based on the T/S relationship derived from XBT data. More salinity data are thus needed, as well as temperature observations deeper than 400 m in the western Pacific, where the subsurface thermal structure shows long-term changes.

The value of this monitoring was particularly evident in 1987, when the hydrological structures were very unusual. The sea surface temperature maps published by the Climate Analysis Center (NWS/NOAA) during our January and July cruises showed a very strong positive thermal anomaly of more than 1° and even 2° in the equatorial Pacific. In January the isotherms rose towards the surface, and a very strong northward current component (more than 60 cm/s) was observed on and north of the equator. The July isotherms were in all cases closer to the surface than during mean July conditions, while a very large eastward flow was observed from 5°S to 10°N. Such an eastward current has never previously been observed in the weste⁻ ᵉquatorial Pacific during July.

Conclusions

In order to understand how and why such large changes occur, monitoring of the Pacific Ocean needs to be improved. We are presently testing a new XBT system which will transmit temperature profiles in real time to data banks and research institutes via the Argos satellite system. Our XBT network should be fully equipped with this system by the beginning of 1988.

Other types of monitoring of the tropical Pacific Ocean are also taking place within the framework of TOGA. In addition to temperature profiles using ships of opportunity (ORSTOM, Scripps, CSIRO), there are studies of mean sea level (University of Hawaii), real-time temperature from moorings (PMEL, Seattle), moored current meters (NOAA, Seattle) and drifting buoys (University of Miami). Such monitoring is of direct interest to fisheries, climate and environmental research in the Pacific.

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PESTICIDES IN THE SOUTH PACIFIC - THE SPREP REVIEW

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ABSTRACT

The report "Pesticide Use in the South Pacific" gives an extensive appraisal of the problems related to pesticide use in the region. It lists kinds and quantities of pesticides used in agriculture, public health, home use, quarantine, forestry and timber preservation. It lists the pesticides used which are restricted or banned in other countries, or are rated as extremely or highly hazardous by WHO. It gives information on major exporters to, and importers and distributors within the region. It lists decision-makers involved in pesticides, noting a regional lack of both expertise to evaluate pesticides and trained manpower to ensure safe and efficient use. It discusses poisoning of humans, domestic animals, fish and wildlife. It outlines the present activities of the limited facilities in the region for conducting efficacy and residue trials, for residue analyses and toxicity studies. Pesticide legislation is reviewed, but most countries lack the expertise and infrastructure necessary for enforcement. Examples of enforcement problems are given. Controls on importation, sale, distribution, labelling, storage, transport and disposal are discussed, as well as requirements for protective clothing and health checks. A bibliography lists publications for the South Pacific and relevant publications from outside the region. It is proposed to establish a Regional Pesticide Information Centre, a Regional Pesticide Advisory Committee, and a Regional Pesticide Residue Laboratory Network. The present status of these proposals is reviewed and future strategies suggested.

Introduction

In April 1983, the South Pacific Regional Environment Programme (SPREP) established a Pesticide Project to review "pesticide use and abuse" in the countries and territories of the South Pacific (SPREP, 1983). This review was broadened to include a study of existing legislation and registration requirements, a review of existing information on the use and problems resulting from the use of pesticides, identification of technical expertise and facilities, and proposals for actions to ensure safe and efficient use of pesticides in the region.

Twenty publications have been produced during this review (see references) or are in preparation, including the main report (Mowbray, 1986a), which was circulated for comment in a preliminary version to each South Pacific country, to international organizations, and to chemical companies in November 1986.

The report gives an extensive appraisal of the problems related to pesticide use in the region. It lists the kinds and quantities of pesticides used in agriculture, public health, home use, quarantine, forestry, and timber preservation. It identifies the pesticides used in the region which are restricted or banned in other countries, or are rated as extremely or highly hazardous by the World Health Organization (WHO). It gives information on the major exporters to, and importers and distributors within the region. It lists decision-makers concerned with pesticides, noting a regional lack of both expertise to evaluate pesticides, and trained manpower to ensure safe and efficient use. It discusses the poisoning of humans, domestic animals, fish and wildlife by pesticides, and outlines the present activities of the limited facilities in the region for conducting efficacy and residue trials, for residue analyses and toxicity studies. The review of pesticide legislation showed that most countries lack the expertise and infrastructure necessary for enforcing the existing or proposed legislation on pesticides. Controls on importation, sale, distribution, labelling, storage, transportation and disposal are discussed, as well as requirements for protective clothing and health checks. A bibliography lists publications directly relevant to pesticide use in the South Pacific region and other relevant publications from outside the region.

The report reviews the status of proposals to establish a "Regional Pesticide Information Centre", a "Regional Pesticide Advisory Committee" (to administer a Regional Pesticide Advisory Scheme), and a "Regional Pesticide Residue Laboratory Network", and suggests future strategies.

Most of the initial information was obtained from a questionnaire. However much subsequent information and updates have been gathered by the author visiting countries and territories in the region, and through correspondence with personnel in governments, companies and other agencies throughout the region.

Reports have been prepared for both the Codex Committee on Pesticide Residues (Hooper, 1987) and for ESCAP (1987) using much of the information collated in the review.

Subsequent to the writing of the first edition of the main report, much more information has been provided by officers of the South Pacific Commission (SPC), governments, companies and non-governmental organizations in the South Pacific and overseas. Assistance on the section on "banned and restricted pesticides" has also been provided by officers of the United Nations, by the Australian, New Zealand and United States governments, and by the International Organization of Consumers Unions (IOCU). These comments, suggestions and data, together with corrections and updates to earlier information and bibliographic listings of recent publications, will be incorporated into a second edition to be published in mid-1989.

In May 1988, the South Pacific Commission (SPC) and FAO will be holding in Noumea a Regional Workshop on the Harmonization of Pesticide Registration Requirements for the Distribution and Use of Pesticides in the South Pacific. SPREP will participate in this workshop, with the author acting as a resource person. It is hoped that materials presented at this workshop and a report on the workshop can be incorporated into the second edition of the review.

To give an overall view of the present situation and of the problems faced to ensure the safe and efficient use of pesticides in the South Pacific Region, information from the review is summarized below. The positive benefits which accrue from the safe and efficient use of pesticides are self evident. The following review concentrates on some of the problems, the objective being to help ensure safe and efficient pesticide use in the region.

Pesticides used in the South Pacific

The number of pesticides (as active ingredients - a.i.) available in all countries of the region has increased greatly in the last ten years (Table 1). Many different pesticides are available, including 60 used in ten or more South Pacific countries (Figure 1). These figures, however, overestimate the numbers, as some pesticides are withdrawn from sale and distribution each year. The pesticides reported as available in French Polynesia and the former Trust Territory of the Pacific Islands (TTPI) countries really reflect the availability in their metropolitan countries.

There are numerous formulations on the market. Different formulations of the same pesticide are used in different countries. Table 2 compares the numbers of active ingredients and formulations available in Fiji, Papua New Guinea (PNG), Solomon Islands, Australia and New Zealand. The numbers of active ingredients and formulations vary from year to year, but they are very high.

The pesticides available in most countries of the region are listed in Table 3. Malathion heads the list. However, availability does not indicate the quantities used. Very little accurate information is available on the quantities used in most countries. Paraquat would be the most used pesticide throughout the region, with an estimated US$ 1 million worth used in PNG alone. The total quantities of pesticides used in selected countries are given in Table 4 and Figure 2. Estimates vary according to the year and the source, and are given by quantity and value.

Table 1: Number of pesticides (active ingredients) reported as available in the SPC area

Country	Number of pesticides 1975-1980	1977-1986
American Samoa	16	43
Comm. Northern Mariana Is.		81
Cook Islands	30	94
Fiji	52	155
French Polynesia	114	418
Guam	33	107
Kiribati		11
Nauru		2+
New Caledonia	50	207
Niue	18	42
Papua New Guinea	65	275
Pitcairn Island		6
Solomon Islands	43	126
Tokelau	4	5
Tonga	40	92
TTPI	39 (includes CNMI)	375
Tuvalu		8
Vanuatu	39	114
Wallis & Futuna		20
Western Samoa	26	84
Unspecified		45
Australia		514
New Zealand		315
Total for SPC countries	162	618
Total including Australia & N.Z.		762
Total available in SPC countries not registered in Aust. & N.Z.		182

Figure 1: Numbers of pesticides (active ingredients) available per country

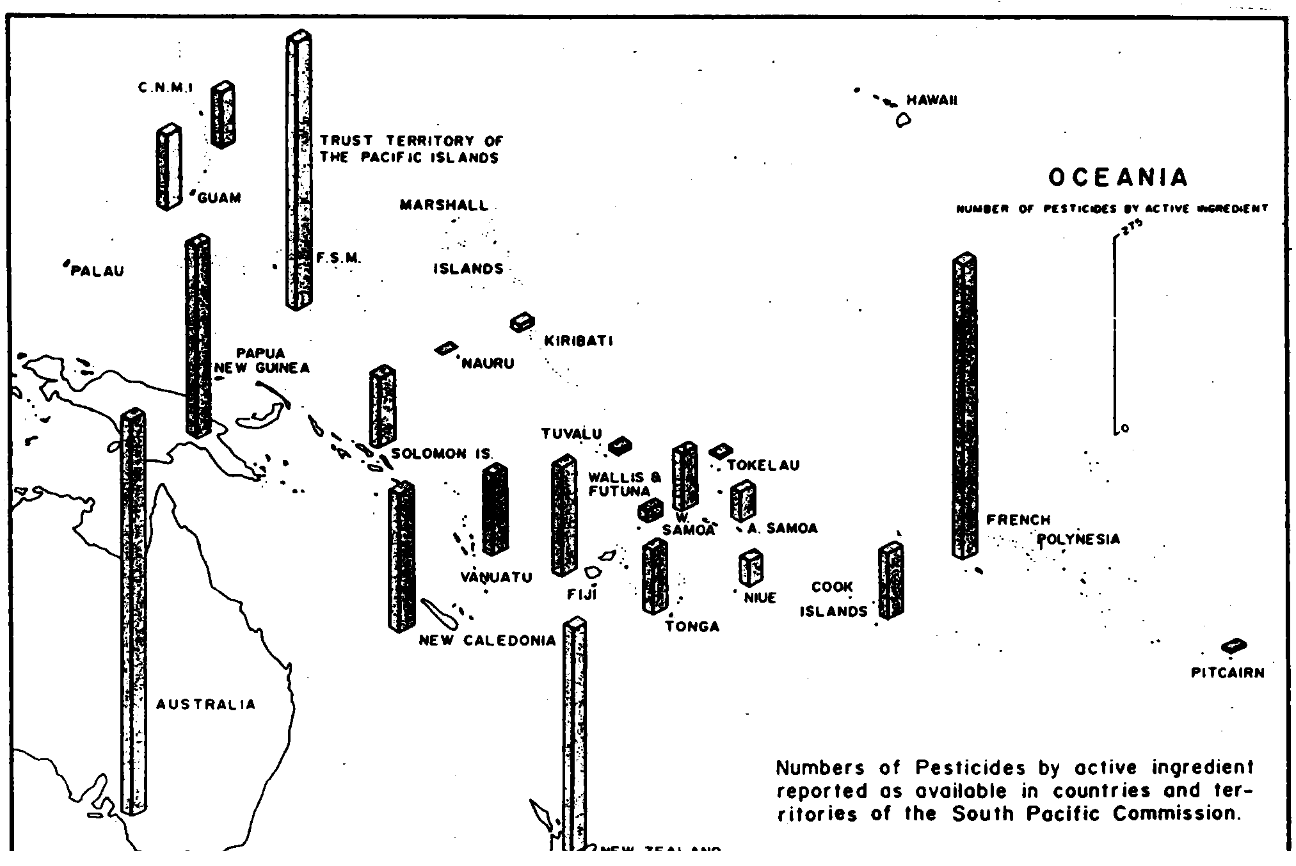


Table 2: Number of recorded pesticides and formulations in selected countries (modified from Mowbray, 1986a)

Country	Number of recorded: pesticides (a.i.)	formulations	Source
Fiji	134	496	Mowbray (1984)
	155		Table 1
PNG	275	824+	Kesu and Mowbray; Table 1
Solomon Islands	98	133	Macfarlane (1984, pers. com.)
	89	174	Abington (1986, pers. com.)
		204	Abington (1987, pers. com.)
	126		Table 1
Australia	370	1874	Snellgrove (PESTLIST, 1983)
	385	2186	Snellgrove (PESTLIST, 1984)
	399	2402	Snellgrove (PESTLIST, 1985); QAC-PESTKEM (1985)
	514		Table 1
New Zealand	287	1213	N.Z. Agricultural Chemicals Board (1982) (agricultural chemicals only)
	367	962	N.Z. Pesticides Board (1983)
	299	850	N.Z. Pesticides Board (1985)
	262	901	N.Z. Pesticides Board (1986)
	315		Table 1

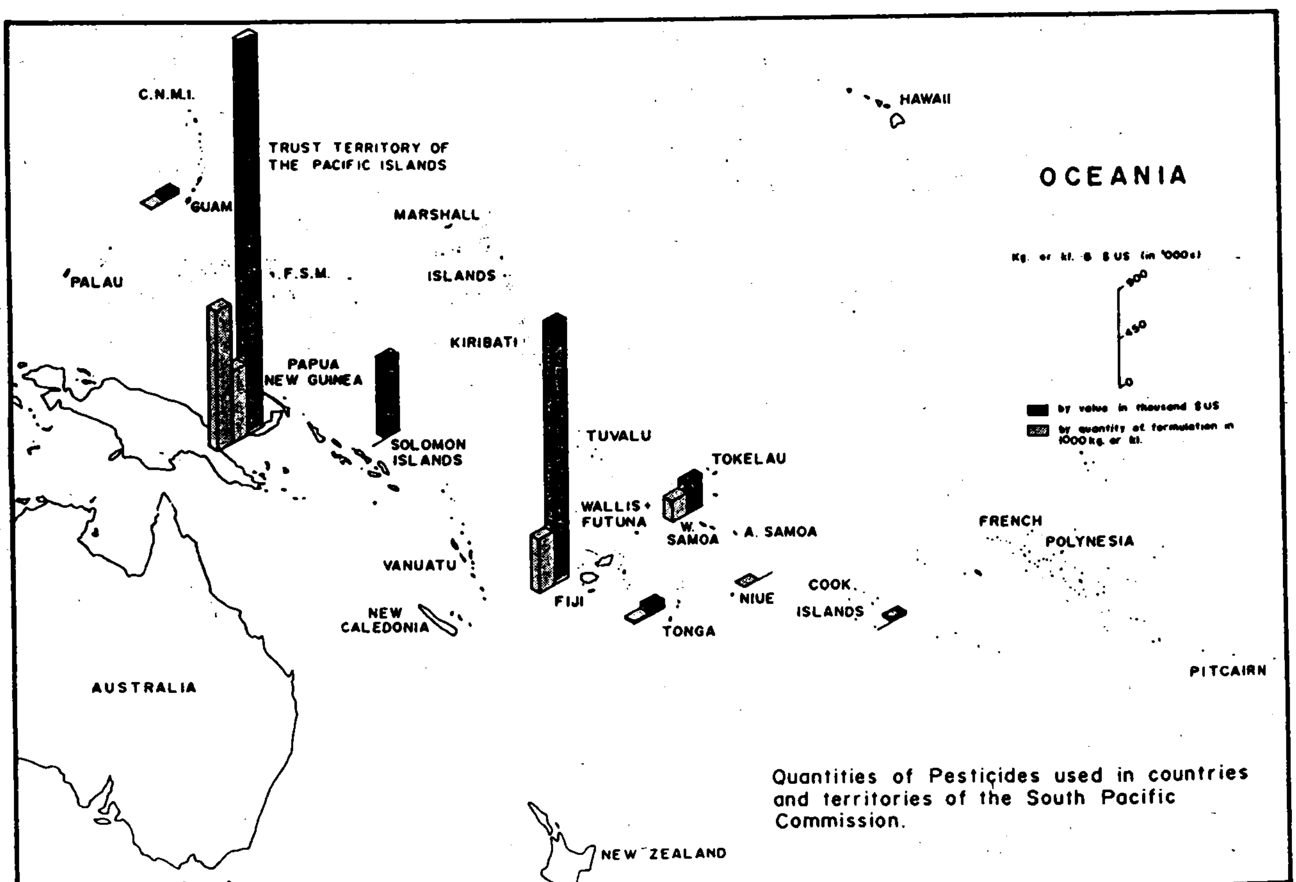
Table 3: Most commonly available pesticides in South Pacific countries

Number of countries in which pesticide is reported as being available	Pesticides
19	malathion (maldison)
16	warfarin
15	benomyl, captan, diazinon, dicofol, glyphosate, methyl bromide
14	carbaryl, dicrotophos, dieldrin, mancozeb, maneb, paraquat, propoxur, temephos, zineb
13	brodifacoum, copper sulphate, dichlorvos, dimethoate, diuron, 2,2-DPA metaldehyde, methomyl, naled, permethrin, pyrethrins
12	acephate, Bacillus thuringiensis, gBHC (lindane), 2,4-D, mineral oil, petroleum oil, pirimiphos methyl, rotenone, 2,4,5-T, white oil
11	bendiocarb, bioresmethrin, chlordane, copper oxychloride, dimethirimol, dinocap, tetramethrin, thiram, trichlorfon
10	atrazine, bromacil, carbendazin, cuprous oxide, endosulfan, fenvalerate*, MSMA, piperonyl butoxide, sulphur, thiram tridemorph, trifluralin

Table 4: Total quantities of pesticides used in South Pacific countries

Country	Period	Quantity by formulation (1000 kg or kilolitres)	Quantity by active ingredient (1000 kg or kilolitres)	Quantity by value (US$ '000)
Cook Islands	1981	-	-	40
	1986	-	-	60
Fiji	1981	505	-	2379
	1985	449	-	1750
	1986	245	-	1380
Guam	1981	8	-	39
Niue	1981	4	-	
Papua New Guinea	1982	788	-	2083
	1982	637	271	-
	1985	1300		3621
Solomon Islands	1981	-	-	724
Tonga	1982-83	20	7	83
	1982			105
	1986	-	-	185
Western Samoa	1981	207	-	313
	1981			370
	1986	-		350

Figure 2: Quantities of pesticides used in selected countries of the South Pacific



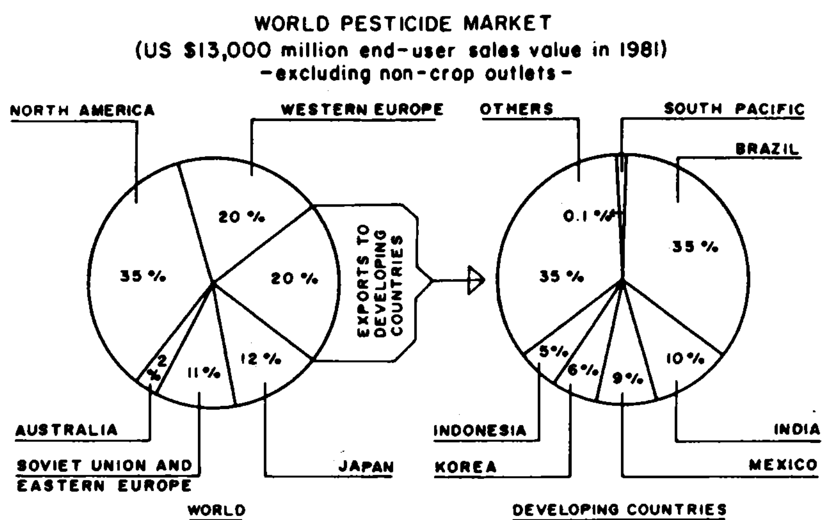
Quantities of Pesticides used in countries and territories of the South Pacific Commission.

GEOG. DEPT UPNG

Papua New Guinea and Fiji are the two major pesticide users. However, in comparison to South-East Asian countries, the amounts used in the Pacific are small. In 1981, it is estimated that 1,450 metric tons of formulated pesticides worth US$ 5.5 million were used in the Pacific, compared to 882,832 metric tons worth US$ 1,969 million in South-East Asian countries (including US$ 900 million worth in China). Since 1981, usage has doubled in some countries such as PNG and Tonga, has increased by 50% in Western Samoa, but has changed little (or decreased) in Fiji. In comparison, by 1985, consumption had increased in most Asian countries, with increases greater than 10% occurring in half these countries over a 5 year period. Excluding China, the total pesticide market in South-East Asia in 1985 was estimated to be worth US$ 1,189 million (Gaston, 1986).

Herbicides are the most used pesticides in Niue and Western Samoa, and for agriculture in Fiji and PNG, whilst insecticides are more commonly used in the Cook Islands, Fiji (total usage), Guam, PNG (total usage), Solomon Islands and Tonga. Fiji and PNG use large amounts of insecticides for domestic use. The use of fungicides in the region is increasing. Figure 3 gives a comparison of types and amounts of pesticides used in selected countries. Figure 4 shows an estimate of the overall proportion of pesticides used in the South Pacific on a world scale. This is probably an overestimate, as the percent value for the South Pacific is more probably less than 0.1%. •

Figure 4: Proportions of pesticides used in the South Pacific compared to the rest of the world



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Banned and restricted pesticides

Much concern has been expressed in recent years over the fact that many pesticides which are restricted, severely restricted for use, or banned in many countries, or are highly toxic, are still freely available in South Pacific countries (Table 5). The reasons for banning or restrictions differ from case to case. Careful analysis shows that the number of such pesticides commonly used in the South Pacific region is not as large as the table suggests.

While the situation is still being investigated thoroughly, it is clear that organochlorines and some highly toxic or hazardous pesticides which have been banned for human and/or environmental reasons are still commonly used (Table 6). In some cases, only particular formulations of some of these chemicals are banned or restricted. Some (e.g. fumigants) are used only by government agencies under strictly controlled conditions. In the South Pacific, however, tropical conditions prevail, minimal protective clothing is used, users are not always well informed, and the enforcement of controls is minimal. It is imperative that countries in the South Pacific restrict the use of chemicals they import to the safer,

Figure 3: Proportions of major types of pesticides used in selected South Pacific countries and in South-East Asia (by value)

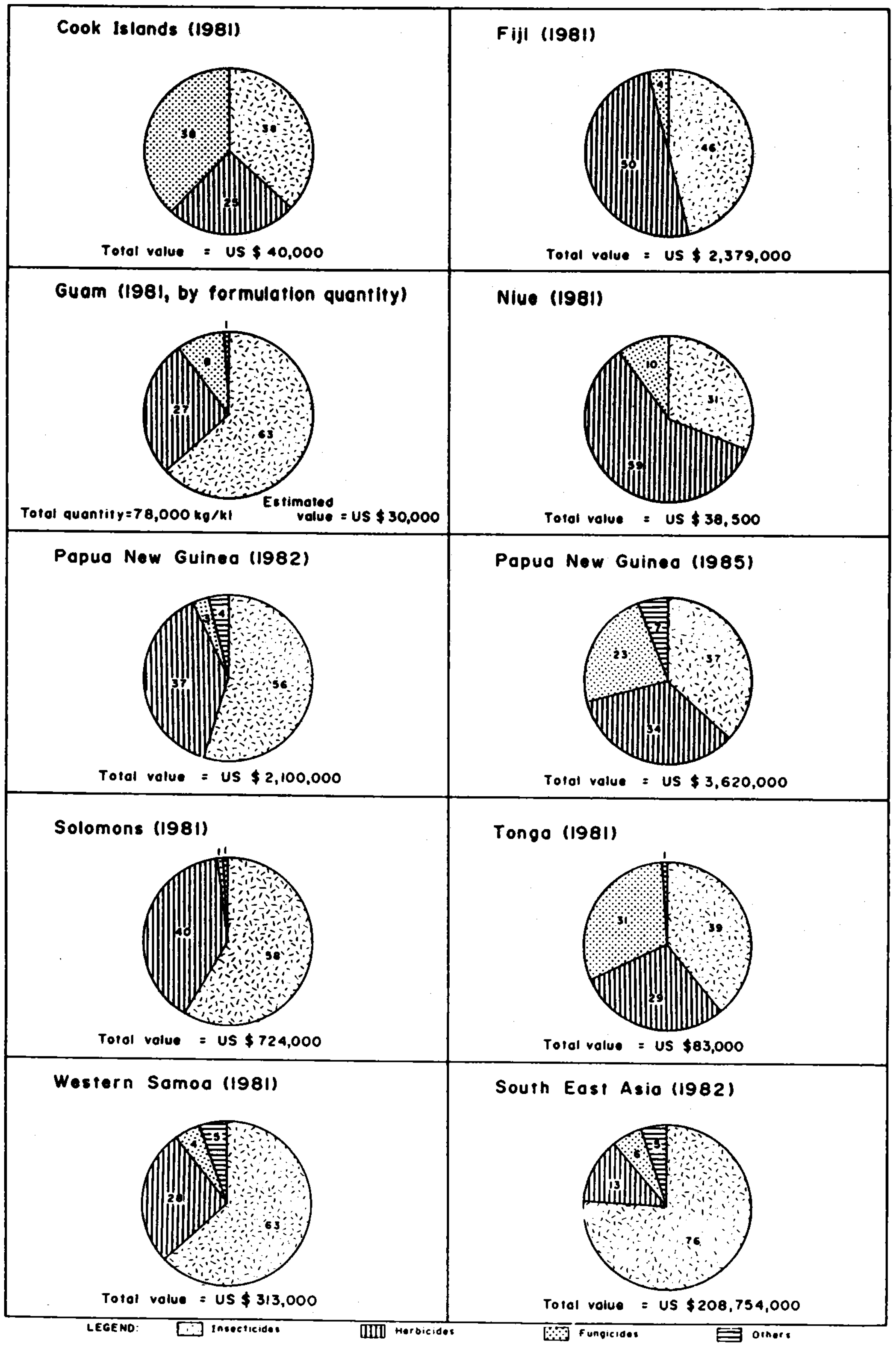

Table 5: Number of banned, restricted or hazardous pesticides (a.i.) available in the South Pacific (includes Australia and New Zealand)

Category	Number
Compounds "banned, withdrawn, not approved" in USA	20
Compounds "severely restricted" in USA	22
Compounds for "restricted use" in USA or its territories	58
Compounds "banned, withdrawn, not approved" in other countries but not USA	66
Total number of compounds "banned, withdrawn, not approved" somewhere in world	86
Compounds in WHO class 1A: extremely hazardous	35
Compounds in WHO class 1B: highly hazardous	59
Total number of pesticides available in the South Pacific	
excluding Australia and New Zealand	618
including Australia and New Zealand	762

[This table should be read in conjunction with the text and not quoted out of context!]

Table 6: Some pesticides banned or restricted in USA or EEC presently used in the South Pacific

acrolein	compound 1080	fenthion	PCP
acrylonitrile	coumafuryl	flouroacetamide	phenyl mercury acetate
aldicarb	2,4-D	fonophos	phorate
aldrin	DDT	heptachlor	phosacetim
aluminium phosphide	demeton	hydrocyanic acid	phosphamidon
amitraz	diallate	isocyanurates	picloram
arsenic compounds	dicrotophos	mercury (all)	pirimicarb
acetates methyl	dieldrin	metham sodium	sodium arsenite
BHC (other than lindane)	diflubenzuron	methamiphos	sodium cyanide
calcium cyanide	dinoseb	methomyl	sodium fluoride
camphechlor (toxaphene)	dioxathion	methyl bromide	strobane
carbofuran	diphacinone	mevinphos	strychnine
chloranil	disulfoton	mirex	sulfotepp
chlordane	EDB	monocrotophos	2,4,5-T
chlordecone	endrin	monuron	TEPP
chlorfenvinphos	erbon	nitrofen	terbufos
chlorobenzilate	ethion	paris green	terbutrylazine
chloropicrin	ethoprop	paraquat	thallium sulphate
	fenoprop	parathion ethyl	warfarin
	fensulfothion	parathion methyl	

Problems associated with use

Within the region there is a lack of trained personnel with expertise to evaluate the real needs for the use of pesticides. There are few trained plant pathologists, entomologists or public health workers with sufficient experience and expertise. Most of those working in the field are "expatriates". SPC, FAO, and research organizations from Germany, France, New Zealand and Australia assist on a consultative-basis. The universities of PNG, Guam and the South Pacific employ and train persons in these areas. Chemical companies provide advice, but most of their employees are sales staff. This situation will be addressed at the Technical Meeting on Plant Protection of the South Pacific to be held in Noumea in November 1987, and at the SPC/FAO workshop on pesticides in May 1988.

Human poisonings

The pesticides which are known to have caused human poisonings are listed in Table 7. The rates of incidence of poisonings by pesticides are given in Table 8. A detailed study on paraquat poisoning in the region has recently been published by the South Pacific Commission (Taylor et al., 1985). Many of the deaths were deliberate and not accidental, particularly among those caused by paraquat. Actual figures for deaths and poisonings due to occupational use are not available or not kept in the region. There is a need for such poisoning information. No information is available on the possible chronic effects on pesticide users; indeed it would be difficult to distinguish such effects. It would seem, however, that the incidence of poisoning in Fiji and Western Samoa is high, and was so in PNG until 1982, when an educational and safety awareness campaign was initiated.

Table 7: Pesticides which have poisoned humans in the South Pacific

Those marked * have caused deaths, although many of these were deliberate, not accidental.

Country	Pesticides
Cook Islands	methomyl, paraquat*, tridemorph
Fiji	diazinon, paraquat*, 2,4-D/2,4,5-T mixture
French Polynesia	paraquat*, PCP, organophosphates
Guam	diazinon
New Caledonia	methaldehyde*, mevinphos, dieldrin, methamidophos, methomyl
Niue	paraquat*
Papua New Guinea	acephate, arsenic, coumaphos, DDT, dichlorvos, dieldrin, dimethoate, methomyl, methyl bromide, methyl parathion, mevinphos, monocrotophos, paraquat*, parathion, propoxur, rotenone*, sodium PCP, trichlorfon, unspecified timber treatment chemical (possibly CCA)
Solomon Islands	diazinon*, unspecified organophosphate or carbamate
Tonga	carbofuran, mancozeb
TTPI (FSM)	endrin, sodium arsenite, methyl bromide
Vanuatu	dieldrin, parathion*
Western Samoa	arsenic trioxide*, mancozeb, paraquat*, tridemorph

(mancozeb and tridemorph cause skin irritation and sensitivity)

Table 8: Accidental and total poisonings by pesticides in selected countries (deaths per 1 million persons per year)

Country	Period	Accidental	Total
Australia	1971-1980	0.05	0.10
	1979-1983	0.18	
New Zealand	1980	0.32	1.6
USA	1979	0.13	
Canada	1979-1983	0.04	
Japan	1979-1983	1.83	
Brazil	1979-1981	0.42	
Papua New Guinea	1969-1984		1.1*
Fiji	1976-1983		16.4*
Vanuatu	1985		21
Western Samoa	1970-1984		89.2*
	1979-1986		122 *

* most cases were intentional (suicide)

Poisonings of domestic animals, fish and wildlife

Very little documented evidence exists on poisonings other than of humans. Only isolated incidents of poisonings have been reported, and many of these lack confirmation. The reports that are available are listed in Table 9. The largest reported kills both involved cattle. In PNG, 44 cattle died after they were sprayed with diazinon which subsequent analysis showed had decomposed into much more toxic breakdown products. In the Commonwealth of the Northern Mariana Islands (CNMI), 75 cattle died after they drank water from an old drum that had originally contained an organoarsenate herbicide. No cases of chronic poisoning due to pesticides (e.g. eggshell thinning) have been reported. No studies have been done to determine ecological effects of pesticide usage on the region's tropical island environments.

Table 9: Poisonings of domestic animals, fish and wildlife in the South Pacific

Country	Report
CNMI	poisoning of cattle by organoarsenate herbicide
Cook Islands	animals killed by oil, and fish by lindane, dumped in streams
Fiji	dogs deliberately poisoned by metaldehyde
French Polynesia	fish in rivers killed by deltamethrin and other agricultural chemicals
New Caledonia	dogs poisoned by organophosphate baits; chickens and ducks by metaldehyde
Papua New Guinea	DDT and lindane killed fish in small creeks and streams; cats and non-target insects in village houses died after DDT spraying (roofs collapsed); cattle killed by dimethoate and diazinon; rotenone (derris) used traditionally to kill fish; DDT and unspecified timber treatment chemical (possibly CCA) used to catch fish
Solomon Islands	fish killed by using temephos illegally
Tokelau	fish and coral killed by lindane; fish kill by DDT
TTPI (FSM)	fish killed by endrin (Truk); large scale kill of fish, wildlife and domestic animals by endrin and sodium arsenite leakage into lagoon (Yap)
Western Samoa	dogs poisoned by licking used paraquat containers

Residue studies

The few studies of pesticide residues done to date have found either low residues, or date whose interpretation has been inconclusive. However, organochlorine residues in some foodstuffs from Western Samoa were above acceptable international residue limits. Only occasionally have people been found with low cholinesterase levels, but such tests are only done sporadically, if at all, in most countries.

No studies have been published on the fate of pesticides after use, although one company has done such a study. Little is known about how active pesticides remain in tropical island environments.

Facilities for residue work in the South Pacific are limited. The Laboratoire d'Etude et de Surveillance de l'Environnement (LESE) in French Polynesia has such facilities, as does the Guam Environmental Protection Agency (EPA) to a smaller extent. With the support of the UNEP Oceans and Coastal Areas Programme (OCA/PAC), the University of Papua New Guinea (UPNG) and the University of the South Pacific have now established small facilities (SPREP, 1986). SPREP and UNEP helped sponsor a training workshop on pesticide analysis held at UPNG in mid-1986 for trainees from both South-East Asia and the South Pacific (Mowbray and Baria, 1986). Two SPREP projects involve monitoring pesticide residues: one is part of a coastal water quality study involving environmental samples (mussel watch); the other involves monitoring of human health (blood residue studies, cholinesterase tests) and checking formulations, doing food analyses, etc. The types of analyses required by country are given in Table 10. The needs of the South Pacific were recently assessed for the Codex Committee on Pesticide Residues (Hooper, 1987).

Table 10: Types of pesticide residue analyses required

Analysis	Country
Cholinesterase tests	Fiji, Niue, PNG, Solomon Islands, Tonga, Vanuatu, Western Samoa
Residues in human blood	Fiji, Niue, PNG, Solomon Islands, Tonga, Vanuatu, Western Samoa
Residues in food stuffs (e.g. meat and vegetable crops)	Fiji, PNG, Solomon Islands, Tonga, Vanuatu
Residues in soils (e.g. lindane)	Solomon Islands
Residues in environmental samples	Fiji, French Polynesia, PNG
Residues in well water and lagoon water	Tonga
Residues in crops in association with experimental trials	PNG, Solomon Islands, Vanuatu, FAO-SPC Plant Protection Project
Checking formulations	Fiji, PNG

Pesticide legislation

The present situation regarding pesticide legislation and registration in the South Pacific is summarized in Table 11. Information required by law for registration and labeling varies between countries, and is summarized in Tables 12 and 13. However, overall the legislation is weak and ineffectual. There is little harmonization of legislation through the region.

Table 11: Summary of the pesticide legislation situation in the South Pacific

Type of control	Country
Own pesticide legislation	Fiji, Solomon Islands, Tonga
About to introduce own pesticide legislation (with New Zealand assistance)	Papua New Guinea
Thinking about introducing own pesticide legislation in near future (with NZ help)	Cook Islands, Vanuatu
Own pesticide legislation, but also under French laws	French Polynesia, New Caledonia
Own pesticide legislation, but also under U.S. FIFRA	American Samoa, CNMI, Guam, TTPI (Federatec States of Micronesia, Marshall Islands, Palau)
No pesticide legislation, but partial control under Poisons Act	Papua New Guinea, Western Samoa
No pesticide legislation, but follow New Zealand regulations	Cook Islands, Niue
No pesticide legislation	Kiribati, Nauru, Tokelau, Tuvalu, Pitcairı Island, Vanuatu
Unknown situation, under French laws	Wallis and Futuna

Most countries admit that their ability to enforce their laws is limited due both to th lack of expertise to evaluate the pesticides and to the inability to enforce the necessar controls. Few countries have an adequate regulatory infrastructure. The planned SPC/FA(workshop on pesticides will assess the legislative needs of the region. Specifically, it wi: discuss the FAO Code of Conduct on the Distribution and Use of Pesticides (FAO, 1986: evaluate the merits of regional harmonization of pesticide registration requirements and ho\ it can be achieved, consider the difficulties of establishing pesticide controls in countrie with small administrations and economies, and develop guidelines for drafting legislation.

Table 12: Information required to register pesticides in Fiji, Papua New Guinea, Solomon Islands and Tonga

Information required	Fiji	PNG(§)	Solomon Islands	Tonga
Trade name	*	*	*	*
Common name	*	*	ISO *	*
Nature of pesticide	*	*	*	*
Formulation	*	*	*	*
Use, including efficacy data, information on application, with holding period	*	*	*	*
Chemical/physical properties	*	(*)	*	*
Analytical methods	*	(*)	*	*
Residue information	*	(*)		*
Toxicological data	*	(*)	*	*
Use precautions	*	*		*
Environmental effects	*	(*)		*
Packaging information	*	*		*
Copy of draft label	*	*	*	*
Name and address of manufacturer	*	*	*	*
Name and address of proprietor/importer	*	*	*	*
Evidence of registration elsewhere	*	*	*	*

§ In PNG, under the new regulations about to be gazetted, most aerosols do not have to be registered. Applicants will not have to submit detailed information in most instances if their products are already registered in Australia and New Zealand. If the product is not registered in either country or another country with acceptable registration procedures, then detailed information on all items listed as (*) will be required.

Table 13: Pesticide labeling information required by law in some South Pacific countries

	Country							
	American Samoa	Cook Islands	Fiji	Guam	New Caledonia	PNG	Solomon Islands	Tonga
Trade name	*	*	*	*	*	*	*	*
Common name and % active ingred.	*	*	*	*	*	*	*	*
Net vol/wt.	*	*	*	*	*	*	*	*
Use category						*		
Directions for use	*	*	*	*	*	*	*	*
Warning and precautionary statements	*	*	*	*	*	*	*	*
Withholding periods	*	*	*		*	*	*	*
Directions in case of poisoning, first aid	*	*	*	*	*	*	*	*
"Poison" label/graphics or colour code	*	*		*	*	*	*	*
Instructions for disposal of container	*	*	*	*		*	*	*
Language requirement (parts only)		* Ma	* E/H/F		* Fr	* E(Tp/M)	* E	* E/T
Citation of registration, and no.	*	*	*	*		*	*	*
Classification (general, restricted)	*			*				
Name and address of manufacturer		*	*	*		*	*	*
Name and address of importer			*	*		*		*

E = English; F = Fijian; Fr = French; H = Hindustani; Ma = Cook Island Maori; M = Motu; Tp = Tok pisin; T = Tongan

Summary and recommendations

Many pesticides are used in the South Pacific. Most countries lack the manpower, technical expertise and infrastructure to advise on the efficient use of pesticides and to enforce effective regulations to control use and abuse of pesticides. Records kept on what pesticides are used are incomplete. Some pesticides used are banned or restricted elsewhere, or classified by WHO as extremely or highly hazardous. Poisonings of humans, domestic animals and wildlife have been reported, and many further reports are unconfirmed. There may be cases not reported. Residue studies are all too small in scale. Very little is known anywhere on the fate of pesticides in small island ecosystems.

What is needed is a regional approach to create:

Regional Pesticide Information Centre able to:

a) collate and compile data on pesticides used in the region, and to compile a "register" for the South Pacific;

b) provide a library service and maintain a bibliography of articles on pesticide use and associated problems in the region;

c) provide individual countries with technical information as required; and

d) conduct/assist with training and educational programmes on safe and efficient use of pesticides within the region.

Regional Pesticide Advisory Committee to:

a) provide collective expertise using persons from within the region;

b) recommend to regional countries and territories what pesticides should be registered or used, for which crop, etc., thus constituting a **Regional Pesticide Advisory Scheme**; and

c) establish guidelines for harmonization of pesticide registration requirements, and suggest other forms of controlling pesticide use in the region, possibly including standardization of labelling.

Regional Pesticide Residue Laboratory Network to:

do small scale monitoring of pesticide residues in water supplies, agricultural products, environmental samples (including "Mussel Watch"), and human tissues, as well as checking formulations and ensuring better co-ordination between existing laboratories.

The problem is that the region lacks the manpower and funds to establish effectively any of the three above. Most countries are poor, with "more pressing development priorities". Most countries will depend for many years to come on expatriates to provide the necessary technical expertise. Very few suitably qualified nationals are available for training in these technical areas.

Both the South Pacific Commission Plant Protection Office and SPREP support the establishment of all three. UNIDO, UNEP, FAO, WHO and ILO all agreed, at an interagency meeting held 21-22 November 1984 on the South Pacific Regional Environment Programme, that the Pesticide Project and the recommendations are very important and worth supporting. These UN and other international agencies have been approached for financial support and technical assistance. However, except for support from the UNEP Oceans and Coastal Areas Programme, from the Intergovernmental Oceanographic Commission (IOC) for the pesticide workshop at UPNG, and now from FAO, and small support from the Environmental Liaison Centre (Nairobi), little assistance has been forthcoming. The above proposals will be presented for consideration at the SPC/FAO workshop, where it is hoped that many of the recommendations will receive support. Efforts will continue to seek funds for the implementation of the proposals agreed to above.

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ENVIRONMENTAL EDUCATION IN THE SOUTH PACIFIC: TOWARDS SUSTAINABLE DEVELOPMENT

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ABSTRACT

For environmental education to have any meaning in the South Pacific, the variety of physical and cultural environments must be taken into account. It is not possible, however, for each country to develop its own programme and thus a kind of "dependent development" which is sustainable can be undertaken. Environmental education is much wider than using formal educational curricula. It should include the use of the media, the employment of environmental economists, and a continuous sharing of information between those who carry out environmental research and those who design and implement policy.

Introduction

A sustainable future for the globe means the repair of soil degradation, the protection and replanting of forests, alternative energy sources and efficiency, a commitment to slowing population growth, maintenance of adequate water quality and quantity, and so on (Brown and Wolf, 1987). All of these issues affect most Pacific nations, and their early recognition will not only assist in slowing global damage but also ensure the viability and sustainability of these tiny societies. In fact, sustainable management of resources in the Pacific may provide a model for the rest of the globe (Dahl, 1984).

A sustainable future for the Pacific, whereby the scattered populations can be fed, housed and employed, cannot be carried out with the high level of financing available to larger societies. Nevertheless, the need for preservation and conservation of resources is equally urgent. In the Pacific, as elsewhere, one cost-effective investment in sustainable development is environmental education, which itself must be sustained to achieve its long-term goals. In this paper, I will discuss whether it is possible to have a type of sustainable development in environmental education in the South Pacific - a sustainable development that will encourage the sustainable development of the larger environment.

The South Pacific environment

Physically there are four island types in the Pacific: large continental islands, volcanic islands, elevated reef islands, and atoll and other low limestone islands. Some island groups consist of more than one island type, and all types are scattered throughout the region (Dahl and Baumgart, 1982). This variety of island types which support approximately 2,000 kinds of ecosystems makes it difficult to generalize about environmental concerns in the Pacific. People who have never left their coral-atoll homes in Kiribati, for instance, can have little appreciation of the range of climates, inland waters and soil types found on the volcanic islands of Samoa, or the continental islands of Papua New Guinea, Fiji, and the Solomon Islands.

Pacific Islands also have a great deal in common, which does lend some support to ideas of regional environmental planning. All countries under study here have coral reefs, which are complex and fragile ecosystems which must be carefully managed if the fishing livelihood of the islanders is not to be threatened. Similarly, most of the countries have mangrove areas which are very important to fish productivity, as sources of firewood, and in helping to control coastal erosion (Dahl and Baumgart, 1982). In many countries the mangrove ecosystems are under threat from the disposal of wastes, the reclamation of land for housing, agriculture or industry, and other advances in the development process.

In Fiji for example, soil degradation as a result of mismanagement and of the land tenure system under which sugar cane is worked, is both rapid and dangerous (Clarke with Morrison, 1987). The fact that the government, management and workers in the sugar industry do not perceive erosion as a hazard is tied in with the belief that land in Fiji is plentiful and will always be cultivable. The lack of security of tenure for the leasehold farmers means that they are disinterested in long-term preservation or conservation, and thus there is little chance for improvement, but to talk of strengthening land rights for leasehold farmers (mainly of Indian descent) would hardly be welcome in the present political climate of Fiji. Both the push for development at any cost, and the land tenure system, "can almost be said to have encouraged the continued misuse of land" (Clarke with Morrison, 1987).

Soil erosion rates in Fiji are calculated to be "36.7 t/ha/year from cane fields on 8 degree slopes, with reasonably good cropping practices, a median value for erosion-control, and located in Fiji's drier zone", a rate far in excess of the 13.5 t/ha/year suggested as the "'soil-loss tolerance level' in tropical areas" (Clarke with Morrison, 1987).

Other environmental problems plague the "pearls" or "jewels" of the Pacific. The lack of safe domestic waste disposal affects 90% of the countries; damage or destruction of productive coastal resources and fisheries is almost universal. The reduction in forest cover, water shortages, solid waste disposal, toxic chemicals and endangered species are all common problems. In particular countries, the issues of mining, industrial pollution, coastal erosion, and nuclear waste disposal and the attendant problems of radioactivity, are of particular concern (Dahl, 1984).

Pesticide use too is a growing problem. In the South Pacific region there are 71 pesticides in use which have been banned, withdrawn or not approved somewhere in the world, and 34 with the WHO classification of "extremely hazardous" (SPREP, 1986). Monitoring the effects of such dangerous pesticides on the population and local environments is being carried out (Mowbray, 1988), but undoubtedly the impacts are major and long term.

Solutions to the problem?

Given the small budgets available to most of the South Pacific countries, as well as their geographical difficulties of isolation, poor transportation, small size and physical diversity, and their dependence on outside powers for government or economic development, it is difficult to conceive of programmes which can solve the present and potential environmental problems of the region. As indicated by Reti (1988), the regional environment programme, with its Convention and mandate to protect the South Pacific environment through research and monitoring as well as education and training, is in the best position to assist in future environmental management. The key question, however, is whether research and monitoring, whether of water quality, logging or pesticide use, once the data collection and publication stages are completed, can be adequately translated into valid educational programmes. These programmes should be suited to the needs of individual Pacific countries, and more importantly, read, understood and acted upon by the people who matter in the whole business of environmental management and planning.

Do government officials, engineers, town planners, architects, city councils, and military leaders really understand the environmental consequences of their actions? Do they care? Are they interested in the fact that excessive logging or untreated disposal of waste materials may have implications for farming, for exports, for security of tenure, for people's livelihoods? Is there any understanding of the long-term costs to a nation in terms of repairing the damage, or of keeping people fed?

Of course a number of these people do recognize that what happens to the environment today has implications for tomorrow, but there is always a tendency to believe that worse disasters happen "somewhere else". The poisoning of a river with an accidental chemical spill causes minor clicking of tongues, but is something which is only to be expected in "other countries". The death of fish in a river in Fiji, for example, is obviously the fault of a rich businessman who must be fined, but does nothing to stimulate a cry for improved (and acted upon) environmental legislation.

Fiji, as the most industrialized country in the SPREP region, has increasing problems of heavy metal pollution as well as all the other problems mentioned. Yet it has only an advisory Environmental Management Committee, which under the last Alliance government, commented on development proposals which might have environmental implications but had no power to insist on changes. Legislation on the books which did make it possible to convict anyone of polluting waterways (Venkatesh et al., 1983), for example, was rarely enforced. Only two countries in the region (Cook Islands and Papua New Guinea) have comprehensive and general legislation for the protection and conservation of the environment (Venkatesh et al., 1983). The more socially oriented and now deposed Fiji Labour Coalition government had no environmental platform except in relation to nuclear testing.

Before environmental legislation can be drawn up and acted upon, an educational programme must take place to convince populations, planners and government officials of the need for continuous research on and monitoring of their environments. But what is environmental education, and how can it be made appropriate to the different needs of the countries? In addition, how can the type of education introduced be sustainable so that it is ongoing, unique to a society's needs, and yet not so individual that the cost of producing programmes is prohibitive, in order that countries benefit from one another's experience and expertise?

Environmental education

Although environmental education is a newly created field in that its principles were not clarified until the Tbilisi conference in 1977, there has been strong interest in incorporating environmental information and interpretation into the various educational systems since the mid-1960's. In fact, views on the meaning of the term have not changed a great deal since those days, with a strong emphasis on:

> "considering the environment as a scientific and aesthetic resource to be used in a life-long educational process, thus making people knowledgeable and aware of the environment and its problems as well as their own role in environmental conservation, preservation and management." (Sytnik, 1985)

Obviously then the environment is considered in its totality, from the physical and natural to the humanly developed, social and political. If people are to be educated in the knowledge and care of their environment, this must also be carried out in a number of ways, not only through the formal education system, but also through the media, the development of practical skills, and integration into every aspect of life, so that environmental education becomes a life-long process.

Environmental education in the South Pacific

Environmental education has a low priority in the plans of individual Pacific Island governments. Regionally, however, there is an environment programme agreed by all the governments, and convention signed by seven of those governments, plus the United States, France, New Zealand and the United Kingdom, which, after ratification, will commit them to avoid polluting the South Pacific by dumping wastes. They have also agreed to establish at least one protected area in each country by 1989.

Only in a few Pacific nations such as Fiji and Papua New Guinea are formal educational institutions funded to an extent which enables them to enact and maintain long-term environmental training and educational programmes. Even in those places, the dependence on fluctuating and declining foreign aid, the shortage of equipment, and the frequent absence of maintenance skills, make the dissemination of information difficult. These difficulties, when added to a variety of government systems, various complex systems of land tenure, the vulnerability of small countries to powerful nations who might wish, for example, to test nuclear devices or carry out mining, make it difficult to devise environmental education and training programmes which are suitable for the Pacific as a region. The programmes which are devised must take the complexities of the Pacific into account and capitalize on regional similarities.

The interpretation of environmental education differs widely throughout the Pacific, and courses or parts of formal syllabuses which might be called environmental studies are very different from one another, ranging from those which teach ecological concepts or conservation, to those which incorporate the role of people within their environment. Where there is a conscious effort to include environmental awareness as part of the syllabus, local examples are generally included, even in countries which operate on an external school system. However, informal community environmental education barely exists in the Pacific region, except traditionally, and the quest for rapid development and cash incomes has meant that traditional methods of resource management and conservation are being forgotten.

Primary schools

Children attend primary or junior school from five or six years until they are about 12 years old. Much of the South Pacific operates on a New Zealand- or Australian-based school system which includes social studies and basic science as part of the school programme. It is in these subjects that the principles of environmental science may be taught, albeit in an indirect manner. For instance, at a very junior level (class 1), students are instructed on the roll of the health inspector and on taking care of their home compound. In basic science they are taught to recognize some plants and to understand the environmental significance of trees.

There have been a number of efforts in recent years to have environmental education taught as a more distinctive part of the school curriculum. In 1979, the South Pacific Commission produced an Environmental Education Handbook and a set of Environmental Mini-Lessons (Falanruw, 1979) for use in primary and secondary schools throughout the Pacific, with the recommendation that they be used either as a complete course of short units on the environment, or as supplementary materials for existing courses. The lessons were distributed and schools asked to trial them. While the private opinion of some educators was that the mini-lessons were not entirely appropriate to every environment, they were considered to be well produced and were readily available. That the South Pacific Regional Environment Programme has been asked to reprint the materials is an indication of the interest in and need for environmental education materials throughout the Pacific.

Since the development of the mini-lessons, SPREP has placed increasing emphasis on producing materials for primary and secondary levels. The Preliminary Annotated Bibliography of Pacific Island Environmental Education Materials and five fact sheets on soils, forests, conservation, coral reefs and pesticides were published in 1985. The demand for these has been so great that SPREP is now producing environmental kits for use in schools which include not only the fact sheets but also environmental games, as well as student work-books and slide and tape sets. Hopefully with an increased awareness of the importance of commencing environmental education at a young age, there will be more resources made available for the production of school materials.

In addition to the work carried out by SPREP, the Institute of Education at the University of the South Pacific (USP) has been assisting individual countries with the development of curriculum in environmental science. At the Primary level, Tuvalu has benefited from a visiting fellow of the Institute who has produced materials for classes 1 to 7.

Secondary schools

Secondary schools in the South Pacific generally place some emphasis on environmental studies. In Fiji, a UNDP/UNESCO Curriculum Development Unit for junior secondary schools produced a social science programme in 1978 which examines the role of people in their environment, resource use, and the interrelationships of all parts of the system. This programme is also used in secondary schools in Tonga, Western Samoa and the Cook Islands. Examples are fitted to the local environment but otherwise the principles remain the same. The Solomon Islands and Papua New Guinea have their own high school systems which also include materials on environmental awareness and management.

Once again the Institute of Education at USP has been active in the development of environmental science programmes. Over the past few years, staff have been assisting education departments in Tonga, Kiribati, Tuvalu, Western Samoa and Vanuatu to develop environmental science curricula for secondary schools. The Institute is also planning to conduct a regional training workshop for curriculum personnel to assist them in incorporating environmental education tenets and skills into the formal educational system. SPREP, through its environmental education programme, is producing case study leaflets for use by later year high school students in geography and environmental studies.

Tertiary institutions

There is a well-developed interest in environmental education and training in the major tertiary institutions of the South Pacific. Both the University of the South Pacific, a regional institution serving eleven countries and based in Fiji, and the University of Papua New Guinea in Port Moresby, have environmental courses and entire degree programmes straddling the arts and science disciplines. Further north in Micronesia, environmental courses are offered at the University of Guam and the Community College of Micronesia at Ponape.

In response to a request from the governments of the region that the University of the South Pacific support the objectives of the SPREP action plan, the University has established a Bachelor of Science in Environmental Studies in order to provide students with a background in both the social and natural sciences. In the programme, the students undertake a science degree majoring in biology, chemistry or physics, as well as completing a programme of geography which includes courses in resource management, human ecology, and food and agriculture in the tropical world, as well as other human and physical geography courses. It is intended that the graduates will find work in offices of the environment (where they exist), or at least will make some environmental input into the national development plans for their countries.

Despite calls by the universities for scholarships to be made available to regional students to undertake post-graduate training in environmental science and resource management within the South Pacific region, to avoid the necessity of sending students overseas and thus risking their non-return, funding has not been procured to date. A major problem for the South Pacific is not only in training graduates, but in keeping them once they have been trained.

Institutions and environmental education and training

It is not only in teaching subjects but also in research that there is a strong emphasis on environmental issues. Some of this research is carried out in association with organizations such as SPREP and UNEP, and also on a regional level through memoranda of understanding between the universities of the region. In 1986, a new organization, the Association of South Pacific Environmental Institutions (ASPEI) was formed to provide regular contact and information exchange between all the institutions working with SPREP. These institutions include not only the Universities of Papua New Guinea, the South Pacific and Guam, but also the Papua New Guinea University of Technology (UNITECH), the East-West Center, Guam Environmental Protection Agency, Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM), Laboratoire d'Etude et de Surveillance de l'Environnement (LESE), and the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC).

The South Pacific Regional Environment Programme has been involved in conducting a number of training activities for environmental educators and managers in the past few years. In addition to various country and sub-regional courses, there was a course in 1982 in Suva on "Environmental Management for Resource Developers" attended by middle and upper level civil servants from ten regional governments. In mid-1985, the Third South Pacific National Parks and Reserves Conference and associated training course were held in Western Samoa. SPREP has also conducted an Environmental Radio Project in which broadcasters were instructed in incorporating environmental materials into radio broadcasts, and it is planning a training course in radio broadcasting for the region. Student fieldwork in Geography and the University of Papua New Guinea has also been funded by SPREP as part of its environmental training responsibility.

The production of environmental materials for a variety of target groups is an increasing concern for the region. Apart from the mini-lessons and fact sheets mentioned earlier, high priority is given to the regular publication of an environmental education journal, and the production of bibliographies, directories and text books. Slide sets, videos and photographic exhibitions have also been produced, either by SPREP or by other institutions with funding assistance, and all are immensely popular throughout the region.

Government departments, committees and legislation

Few South Pacific countries have recognized the importance of environmental management to the extent of Papua New Guinea, which has an Office of Environment and Conservation. There is, however, a great deal of environmental legislation in different Pacific countries (Venkatesh et al., 1983). The legislation mostly concerns the management of water and wildlife, but enforcement is inadequate. As the Conference on the Human Environment in the South Pacific in 1982 in the Cook Islands was informed:

> "No country appears to have an environmental statute which completely meets its needs, probably because many have been modelled on examples only marginally relevant to their circumstances. Emphasis often lies on the aesthetics of environmental protection rather than the imperative of resource conservation." (Dahl and Baumgart, 1982)

Generally, South Pacific nations have a committee as part of another department, or straddling several relevant departments, which advises government on environmental policy. In Fiji, despite the deposition of the Coalition government and the defeat of the previous government, there still exists the interdepartmental Environmental Management Committee (EMC) which is an advisory body only. Had the Coalition cabinet been able to complete its business this year, an Environmental Management Unit would have been established within the Directorate of Town and Country Planning, co-ordinated by a principal environmental officer. The unit had been proposed by the former Alliance government, and was a positive sign that Fiji was finally moving towards formalizing protection and management of the environment. It is difficult to say in Fiji's present circumstances, which include a rapid decline towards bankruptcy, what importance the environment will have. If rampant development has to stop due to budgetary constraints, perhaps certain environments will be spared destruction, however inadvertently, and at whatever human cost. On the other hand, the inability of government departments to carry out normal monitoring procedures at the present time, and the despair felt by Fiji citizens of whatever race, could also mean that the environment is very low in anyone's set of priorities.

Community education

There are very few organizations in the South Pacific which emphasize public or community environmental education. The National Trust of Fiji is concerned with conservation and education, and each year co-ordinates National Environment Week which usually involves a seminar and public lecture series, poster competitions and displays, and an oratory contest. At the University of the South Pacific, the South Pacific Action Committee on Human Ecology and the Environment (SPACHEE), which started in 1982, is playing an increasing role in co-ordinating personnel within and outside the university, as well as collecting information on environmental research and education, and actively participating in campaigns on environmental issues. Along with the National Trust of Fiji, SPACHEE is making good use of the media and is looking towards the introduction of television into Fiji in 1989 as a vehicle for publicizing issues of environmental concern.

Throughout the Pacific, non-governmental organizations such as Ofis Blong Meri, the YWCA, various women's interest groups, and the Pacific Council of Churches are the main focus of environmental concern, although few of them highlight the environment as their strongest interest, mainly because Pacific people have many other aspects of everyday living to worry them at present. In Papua New Guinea, the Melanesian Environment Foundation, a non-secular community-based non-governmental organization, commenced operations in 1986. The organization aims to prepare and distribute environmental education kits and receives funds from SPREP.

The success of environmental education programmes

Despite the apparently high level of environmental awareness in the South Pacific, with the existence of committees, legislation and relevant school programmes, it would be a mistake to regard the whole of the South Pacific and its inhabitants as being environmentally conscious. Despite the wide use of some of the school curriculum materials, each country has its own interpretation of what is meant by environmental education. An example of the different views of such programmes may be found in the UNEP Asia-Pacific Report on Environmental Co-operation (1982) where the comment was made that:

> "In the Pacific, churches are especially effective community centres which can be used for environmental education. Also the key role of women as homemakers makes them ideal promoters of environmental awareness." (UNEP, 1982)

This narrow view of "environment", meaning the care and nurturing of the immediate home environment, may be a good introduction to environmental awareness for a child, but it does not tackle the broader issues of understanding the earth as a system, and all the relationships of the components of that system.

Some governments, such as the Cook Islands and Western Samoa, make no mention of environmental education in their development plans, but in Fiji, Papua New Guinea, New Caledonia and the Solomon Islands, there are comments on stimulating public awareness, not only through the formal educational system but also through media campaigns. In Papua New Guinea, for example, there is a weekly environmental column in one of the newspapers. In Fiji, a nature column plays a similar role, and a locally produced science journal for high school students carries a number of useful and popular articles.

Media campaigns alone, however, cannot heighten environmental awareness to a level where people no longer need to be reminded of its importance. A combination of formal programmes in educational institutions, the operation of training courses, recognition by governments, and the dissemination of videos, posters and other materials, as well as increased research into environmentally related fields, may provide the stimulus needed for an environmentally aware society. Even then, it is difficult to conceive of programmes which suit the needs of the twenty-two physically, culturally, politically and economically diverse nations of the South Pacific. While some countries view environmental education as something which must be integrated into the school system, others feel it should be taught as a separate subject (see Bryant, 1984). Generally, however, it has been established in the Pacific that environmental education is important to balanced development. As an environmental consultant in the Solomon Islands has recently stated:

> "Legislation will always be necessary as a basis for legal action to curb wilful resource destruction and environmental damage. However, education is the ultimate key to a genuine appreciation of how each person relates to the environment and resources and what that person's obligations are.... Effective environmental understanding in the community requires some measure of education from the earliest years of school." (Baines, 1981)

In this, Baines is in agreement with educators throughout many parts of the South Pacific who feel that "environmental education embraces the full spectrum of human behaviour..." (Fiji Ministry of Education and Youth, 1983).

Sustainable development of environmental education?

What are the most suitable kinds of environmental education programmes for the diverse Pacific environments? Numerous materials are now available for formal education, but communities at large have little consciousness or understanding of the necessity to protect and preserve what remains of their natural environment. Rapid urbanization, the change from subsistence to cash economies, increasing population pressure on some land areas, and the demand by outside powers for a share of ocean resources mean that Pacific Islanders are under constant pressure to take from, but make no promise to give to, their environments. Unfortunately, not even environmental disasters stimulate the development of community action groups, except for a widely shared concern about nuclear testing which, while morally reprehensible, will cause far less harm to the health of Pacific Islanders than pesticide misuse.

There is a great deal of research being carried out on environmental problems. The concern is now to relay the results of that research to governments and their people and to integrate the need for environmental education into development planning. Perhaps the most practical way of doing this is by demonstrating to each country the long-term financial and human costs of mismanaging an environment. This would require environmental accounting or cost-benefit analysis studies which would clearly demonstrate to planners the impact on a national budget of, for example, logging native timber for export and immediate cash returns, without replanting. Only then can we hope for governments to agree to Environmental Impact Assessment reports before any major development project is undertaken.

Environmental education is much wider than merely incorporating material of environmental significance into school and university curricula. That is a good place to start, but it should always be carried out in conjunction with media campaigns (such as envisaged by the SPREP radio broadcasting project), development planning, and legislation. Environmental education must be integrated and not introduced in a piecemeal fashion throughout the public and formal education channels, but this requires commitment by planners. That commitment will come only when planners can see direct relevance to their own particular social, cultural, economic and political systems. Just as population planning throughout the world has finally become an integral part of "human resource development", so too should those involved in environmental research and education throughout the South Pacific be prepared to view environmental education as an integral part of national development.

Before such an awareness can be widely developed, however, "constituencies" need to be created. Constituencies consist of people who care about the protection and conservation of certain things within the environment and are prepared to "advocate and fight on their behalf" (Riley, 1986). A constituency then is essentially the politicization of environmental issues. Encouraging people to visit areas which should be protected, if carefully managed, could be an important step in raising their consciousness. Making films and advertisements for television can also be an effective way of arousing public sympathy. Once the awareness exists, and, most importantly, the desire to defend the environment develops, the creation of environmental groups will occur and political support will have to follow. With political support, or at least campaigning, the integration of environmental education and legislation into development planning will occur.

Part of the attempt to arouse constituency interest in the environment is the publication of scientific research in a popular form. Scientists have an obligation to do this and to make submissions to development planning offices when national development plans are being drawn up. There should, in other words, be less mystique about the results of significant scientific research. Such efforts may be time-consuming and beyond the realm of many researchers. This is where the role of regional bodies such as SPREP becomes important. The dissemination of research findings should go not only into curriculum materials for schools, but also to open public forums, the media and government planners. Perhaps as an immediate first step, an environmental economist could be employed to cost the impact of some environmental disasters in the Pacific, and present the results to governments. Since trained environmental economists are rare, or possibly even non-existent in the South Pacific, then urgent priority should be given to their training. Such environmental accounting, combined with public education programmes and a continuing emphasis in the school curriculum on the value of the environment, will go a long way towards making environmental education sustainable.

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ENVIRONMENTAL PROTECTION IN THE NORTH-WEST PACIFIC

CONTROL AND MONITORING OF MARINE POLLUTION - JAPANESE APPROACHES

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ABSTRACT

Marine pollution is a major concern in Japan, and pollution countermeasures have been applied. In the metropolitan bays and the Seto Inland Sea, an area-wide pollution load control system has been applied to limit the pollution load in terms of chemical oxygen demand (COD), but improvement is very slow. In other coastal seas, stringent effluent controls have been applied to industries, and much of the coast has been designated as natural parks and nature conservation areas. Pollution of the open seas must be controlled through international agreements. Regular monitoring of offshore marine pollution has shown some improvement over the last several years, but continuing efforts to control pollution are still required.

Introduction

Japan is an archipelagic country surrounded by the Pacific Ocean, the Japan Sea and other seas. Its long shoreline, totalling 32,500 km, is the site of intensive agricultural, fisheries and industrial activities. Marine transport, both domestic and international, is also intensive in Japanese waters. Marine pollution issues thus constitute a major concern as part of environmental protection, and pollution countermeasures have been applied both domestically and internationally (Figure 1).

Environmental quality standards have been set for coastal waters, including water quality standards for toxic substances related to the protection of human health (Table 1) and those related to the conservation of the living environment (Table 2). With respect to toxic substances, over 1,300 sites were checked for compliance with these standards, and during the 5 year period 1981-1985, only one site exceeded one standard (lead) on one occasion. The compliance rates for the living environment standards for all coastal waters and for the major metropolitan bays are shown in Figure 2.

Table 1: Water quality standards to protect human health (maximum values; average annual values for total mercury)

Cadmium	0.01 ppm or less
Cyanide	Not detectable
Organic phosphorus*	Not detectable
Lead	0.1 ppm or less
Chromium (VI)	0.05 ppm or less
Arsenic	0.05 ppm or less
Total mercury	0.0005 ppm or less
Alkyl mercury	Not detectable
PCBs	Not detectable

* Organic phosphorus includes parathion, methyl parathion, methyl dimenton and EPN

Figure 1: The legal system for water quality management in Japan

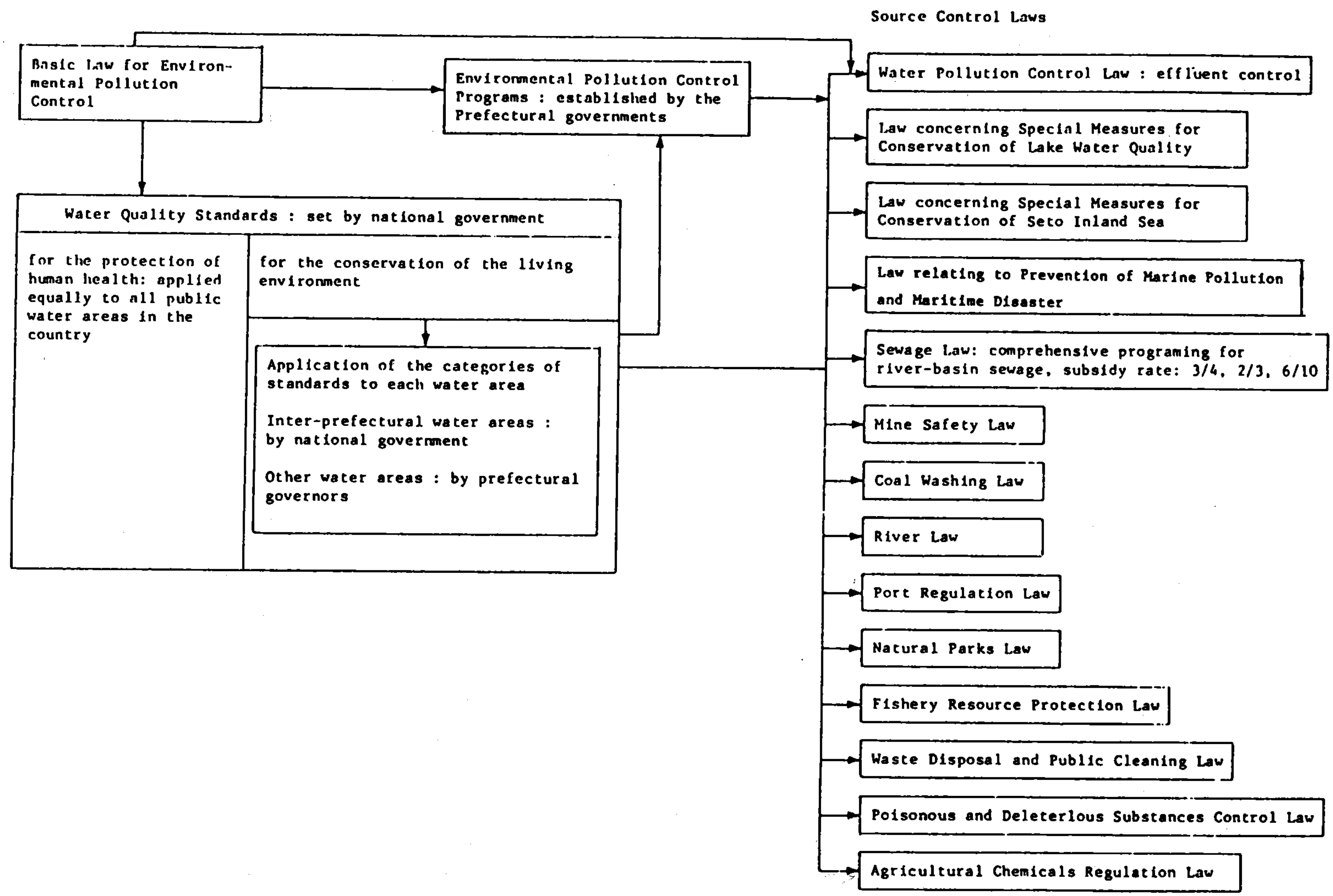


Table 2: Water quality standards related to conservation of the living environment

Coastal Waters

Category	Item / Purposes of water use	Standard Values*				
		pH	Chemical Oxygen Demand (COD)	Dissolved Oxygen (DO)	Number of Coliform Groups	N-hexane Extracts
A	Fishery, class 1; bathing; conservation of natural environment, and uses listed in B-C	7.8 - 8.3	2 ppm or less	7.5 ppm or more	1,000 MPN/100 ml or less	Not detectable
B	Fishery, class 2; industrial water, and uses listed in C	7.8 - 8.3	3 ppm or less	5 ppm or more	-	Not detectable
C	Conservation of the environment	7.0 - 8.3	8 ppm or less	2 ppm or more	-	-

* With regard to the quality of fishery, class 1 for planting oysters, the number of coliform groups shall be less than 70 MPN/100 ml.

Notes; 1. Fishery, class 1; For aquatic life such as red sea-bream, yellow tail, seaweed and those of fishery, class 2.
Fishery, class 2; For aquatic life such as gray mullet, laver, etc.

2. Conservation of the environment: Up to the limits at which no unpleasantness is caused to people in their daily life (including a walk by the shore, etc.)

Figure 2: Compliance rate for environmental quality standards for the living environment in coastal waters

(%)

Water areas \ Year	'74	'80	'81	'82	'83	'84
Coastal water areas	70.7	79.8	81.6	81.3	79.8	81.3
Tokyo Bay	44	61	61	61	61	61
Ise Bay	47	53	59	41	53	47
Seto Inland sea	67	72	81	81	81	81
Osaka Bay	67	67	75	67	67	67
Others	77	85	84	84	81	84

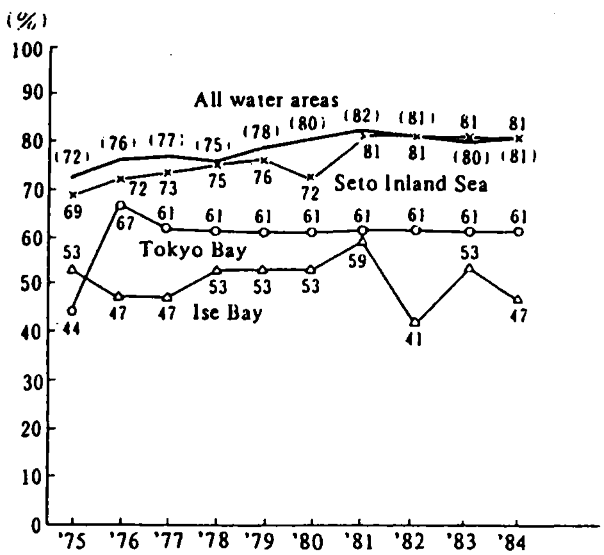
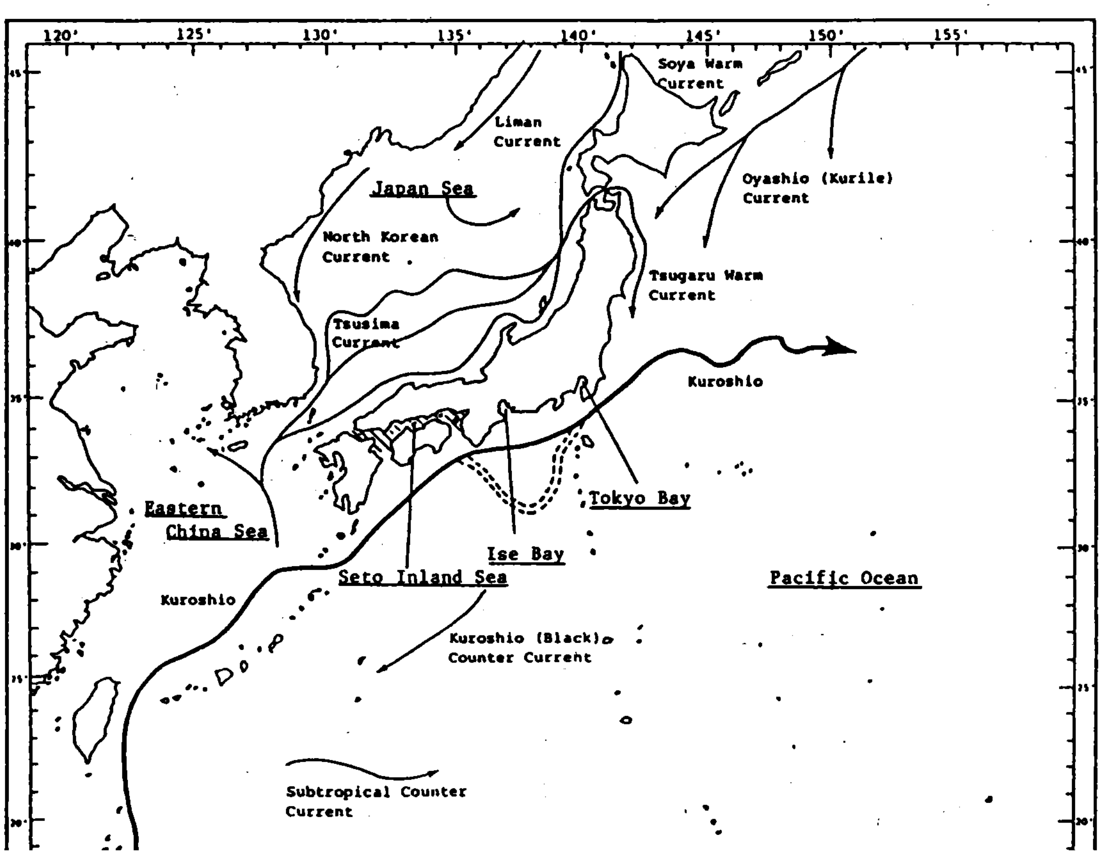


Figure 3: Seas and ocean currents in and around Japan



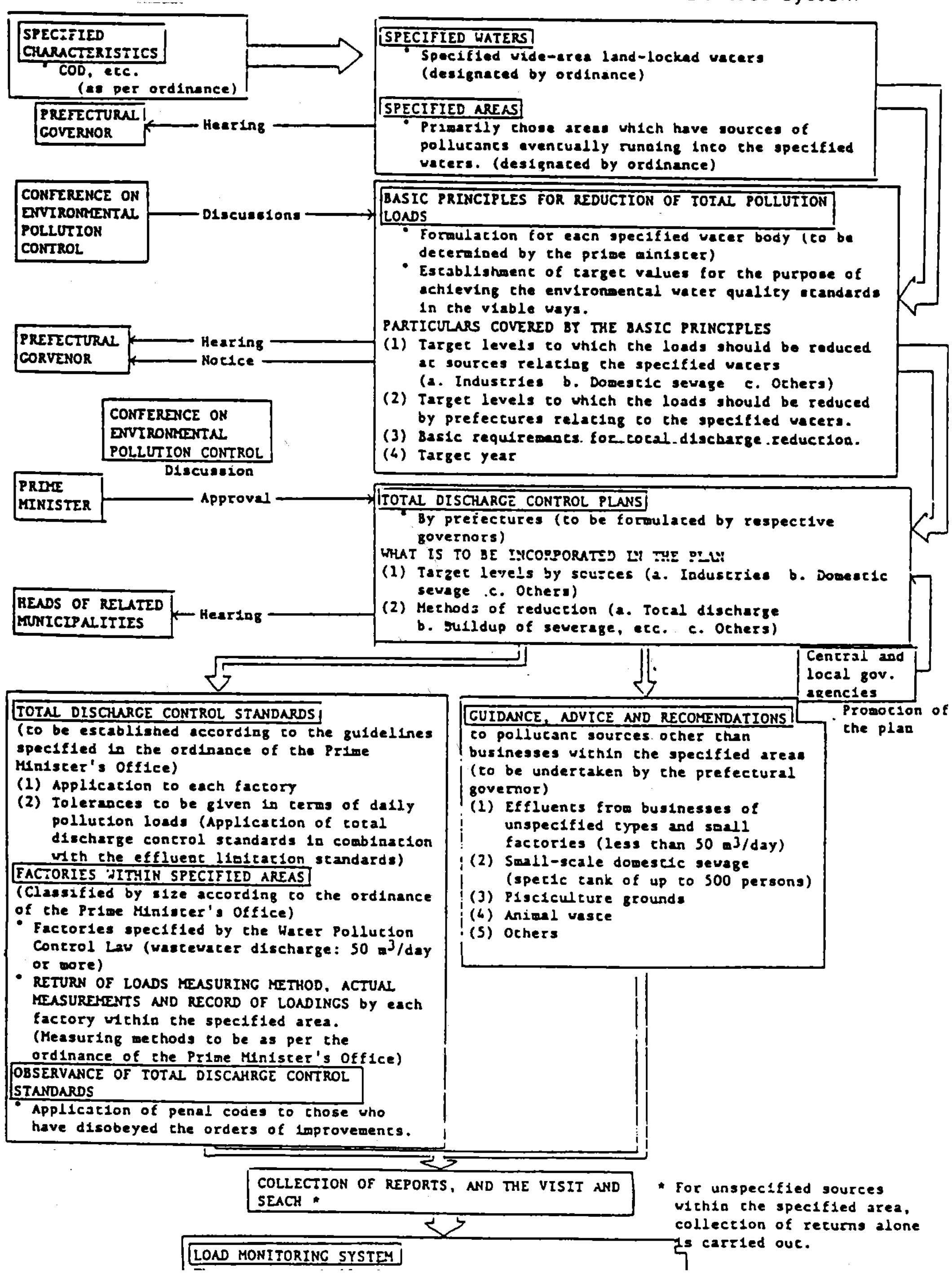
For the purposes of describing the different pollution control approaches, the seas in and around Japan may be divided into:

- metropolitan bays and the Seto Inland Sea,
- other coastal seas, and
- the open seas (Figure 3).

Metropolitan bays and Seto Inland Sea

The large populations and intensive industrial activities of the two metropolitan bays, Tokyo Bay and Ise Bay, put strong pressure on the marine environment. Poor exchange of water with the open sea makes the pollution particularly conspicuous in these areas. Effluent standards in terms of concentration (mg/l) are not always sufficient in these cases. In view of this, a special measure, the Area-wide Pollution Load Control system, has been applied to limit the total pollution load from the hinterland in terms of chemical oxygen demand (COD) (Figure 4).

Figure 4: Outline of the Area-wide Pollution Load Control System



The prefectural governors concerned have fixed COD pollution load control standards based on a COD pollution load reduction plan for industries and municipalities within each specified drainage area (Figures 5 and 6). This system was first applied in 1979 with the target year of 1984. The revised control plan (1984-1989) is now in effect, leading to further reduction of the total pollution load.

Figure 5: Pollution load reduction plan for Tokyo Bay

Prefecture	Targeted COD loading (tons/day) in 1989			
	Domestic	Industrial	Others	Total
Saitama	81	29	9	119 (91)
Chiba	45	13	5	63 (95)
Tokyo	89	21	18	128 (85)
Kanagawa	34	15	6	55 (83)
TOTAL	249 (86)	78 (94)	38 (95)	365 (88)

(Figures in parentheses indicate the percentage of the targeted COD loading compared to 1984 levels.)

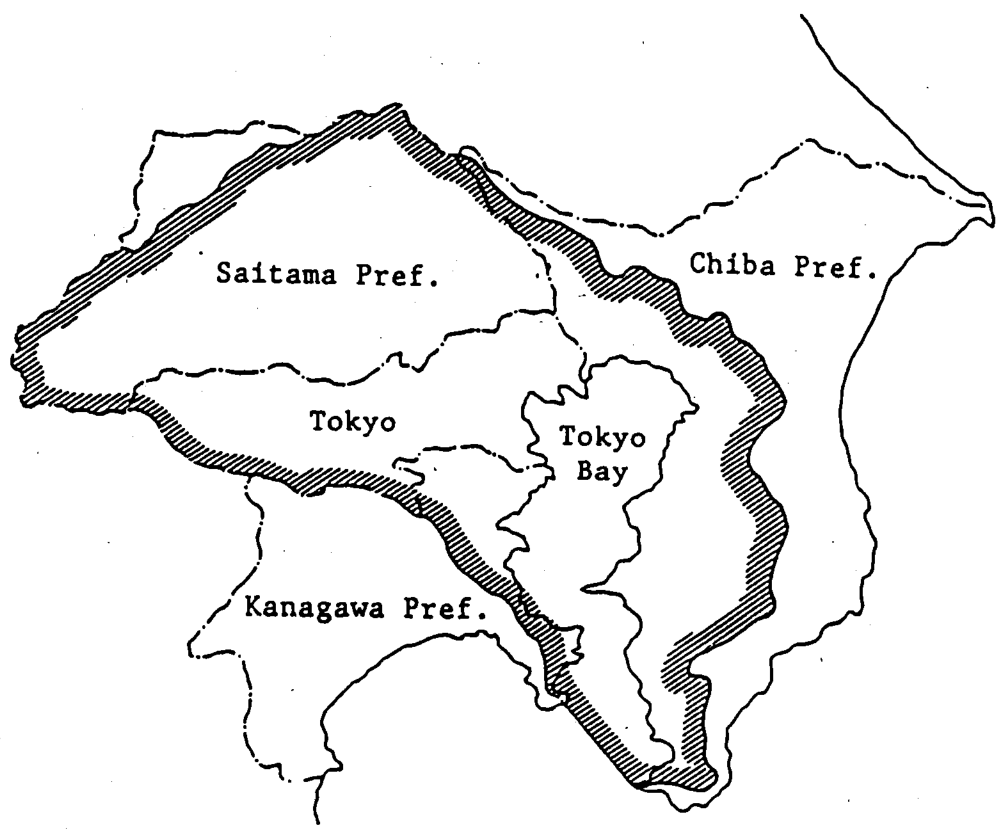
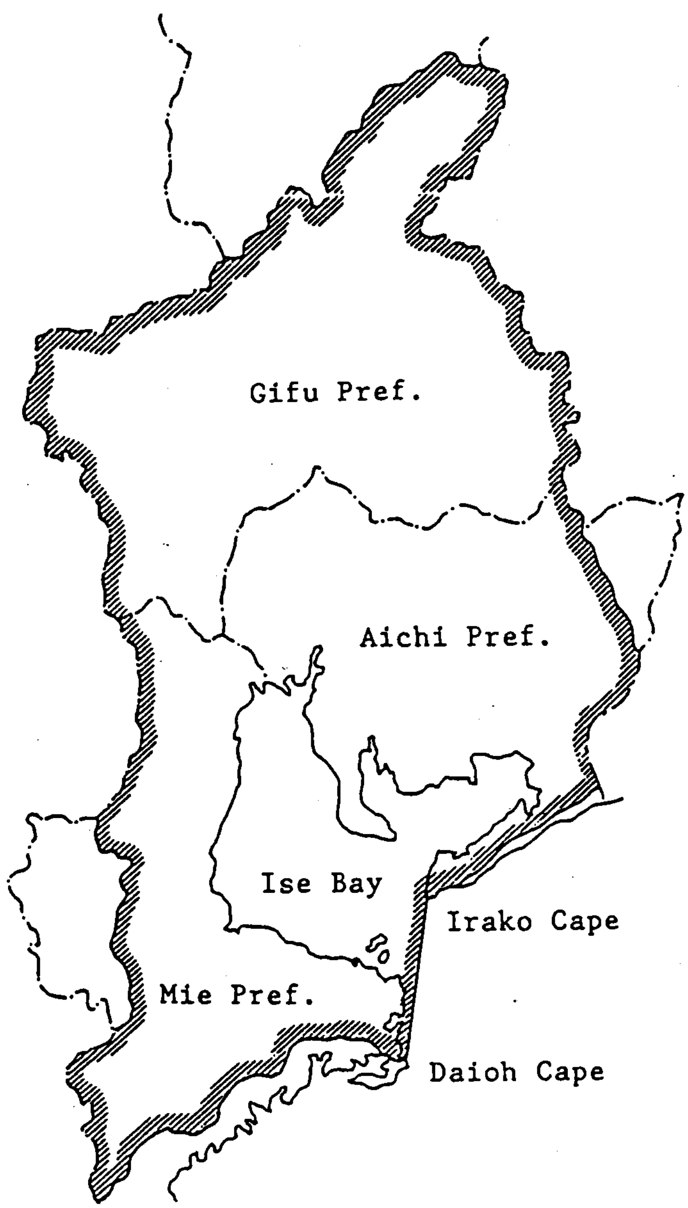


Figure 6: Pollution load reduction plan for Ise Bay

Prefecture	Targeted COD loading (tons/day) in 1989			
	Domestic	Industrial	Others	Total
Gifu	31	29	8	68 (96)
Aichi	83	50	20	153 (94)
Mie	26	19	6	51 (98)
TOTAL	140 (93)	98 (97)	34 (97)	272 (95)

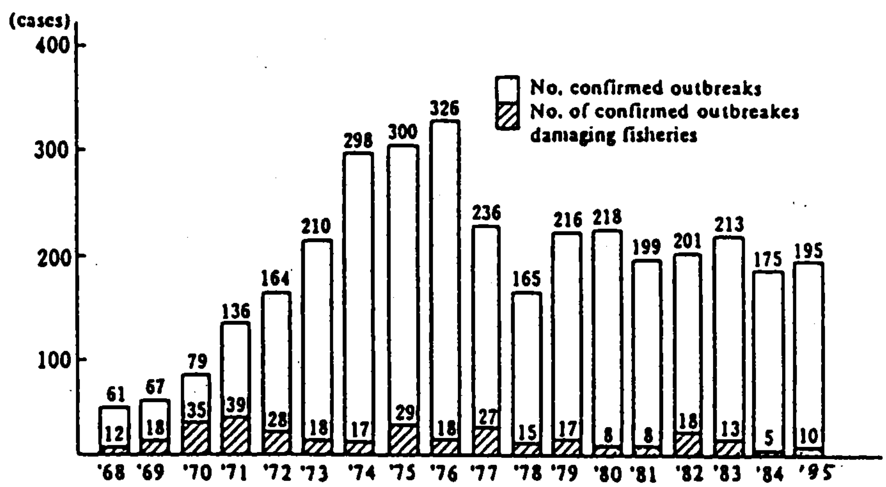
(Figures in parentheses indicate the percentage of the targeted COD loading compared to 1984 levels.)



Despite these efforts, the improvement of water quality in these bays in terms of COD is very slow, and eutrophication problems such as red tides persist. Continuing demands for land reclamation and waste disposal, as well as changes in waterfront use patterns (residential and recreational uses are increasing), make these metropolitan bay areas a focal point of marine pollution control and environmental planning.

The Seto Inland Sea has also supported large industrial activities and populations along its shoreline. For example, it includes Osaka Bay which receives waste water from two metropolitan cities, Osaka and Kobe. On the other hand, the Sea has long been praised for its scenic beauty, and most of its shoreline is designated as a natural park area. It also contains valuable fisheries resources. In the 1960's, this semi-enclosed sea area became rapidly polluted, as illustrated by an increasing number of red tide outbreaks (Figure 7). Baseline measures under the Water Pollution Control Law were not sufficient to curb the pollution. The resulting demands for vigorous enforcement of measures for environmental conservation and the preservation of water quality led to the enactment of an Interim Law in 1973, which was revised to include new policies in 1978, becoming a permanent Law concerning Special Measures for Conservation of the Environment of the Seto Inland Sea.

Figure 7: Yearly changes in the number of confirmed outbreaks of red tide in the Seto Inland Sea



Source: Fishery Agency

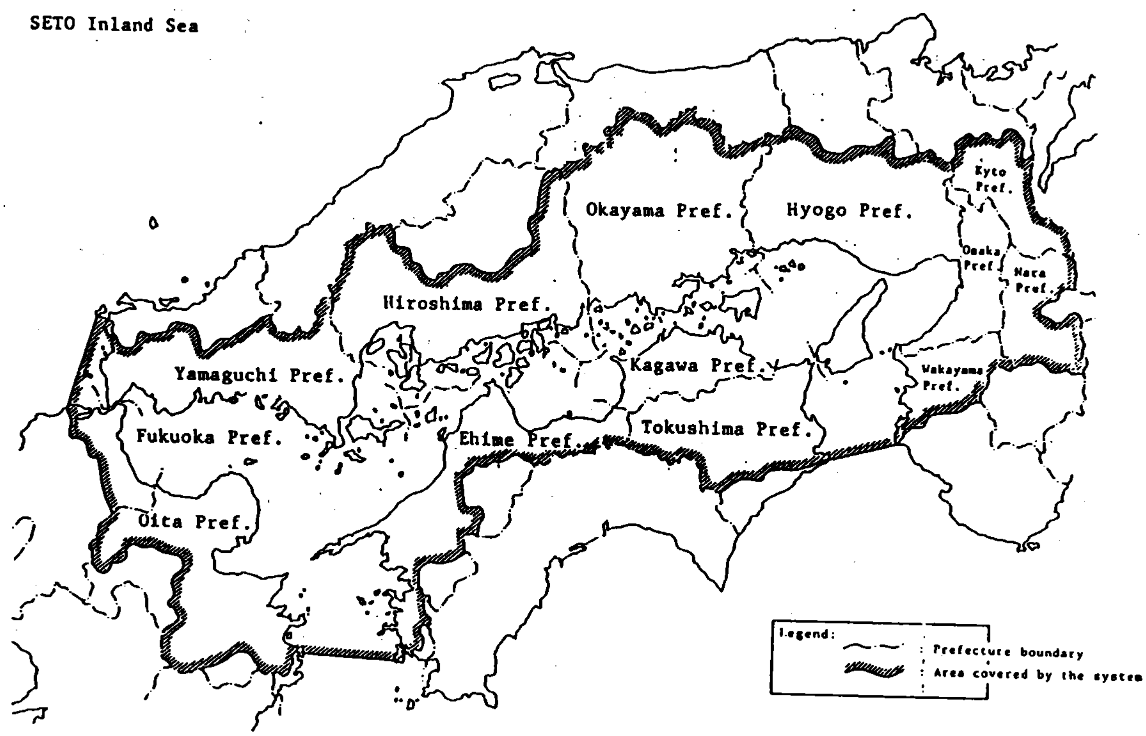
Under the law, the governors of the 13 prefectures concerned are implementing environmental conservation measures in their respective regions based on prefectural plans adopted in July 1981. The installation or alteration of specified facilities is subject to permission; in 1983, 560 applications for installation and 652 applications for alteration were permitted.

In response to the basic guidelines for reducing total pollution loads in terms of COD under the Water Pollution Control Law, and the special measures for the Seto Inland Sea, the prefectures established plans in March-April 1980 for Area-wide Pollution Load Control. In order to prevent eutrophication, special guidelines were adopted for reducing phosphorus and its compounds. After a first phase targeted for 1984, the Eutrophication Prevention Subcommittee of the Seto Inland Sea Environmental Conservation Council proposed new measures, on the basis of which the prefectural governors adopted new guidelines for reducing phosphorus and its compounds in April-May 1986 (Figure 8).

Figure 8: Pollution load reduction plan for the Seto Inland Sea

Prefecture	Targeted COD loading (tons/day) in 1989			
	Domestic	Industrial	Others	Total
Kyoto	26	13	4	43 (93)
Osaka	99	31	7	137 (90)
Hyogo	57	45	14	116 (91)
Nara	20	5	2	27 (90)
Wakayama	16	21	2	39 (98)
Okayama	34	27	11	72 (95)
Hiroshima	37	36	9	82 (94)
Yamaguchi	22	59	5	86 (93)
Tokushima	16	21	7	44 (100)
Kagawa	18	9	6	33 (100)
Ehime	26	44	8	78 (98)
Fukuoka	12	14	4	30 (97)
Oita	19	30	8	57 (95)
TOTAL	402 (91)	355 (97)	87 (98)	844 (94)

(Figures in parentheses indicate the percentage of the targeted COD loading compared to 1984 levels.)

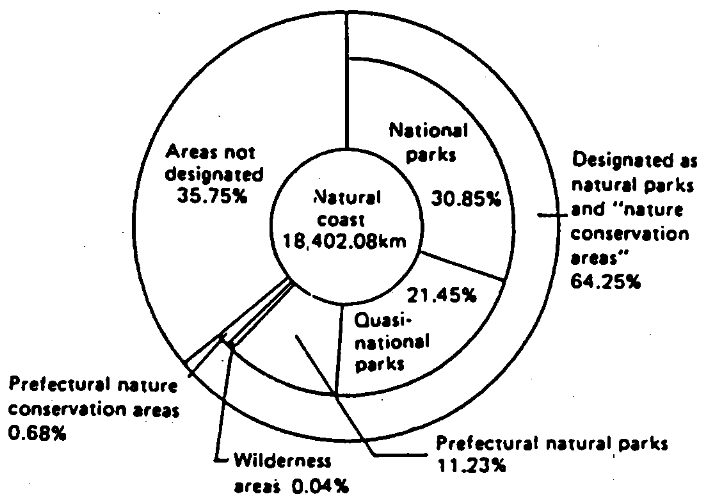


Other coastal seas

The seas along the coast of Japan other than the metropolitan bays and the Seto Inland Sea, were not exempted from pollution in the high-growth period (1960-1975) due to rapid industrialization. Large petro-chemical and steel industry complexes were constructed along the coasts and in several bays (e.g. Kashima industrial complex and Dokai Bay). Due to stringent effluent regulations and efforts by local governments and industries, once heavily polluted industrial ports and bays have shown significant improvements in water quality. Remedial measures for the past still continue, such as compensation for the victims of organo-mercury pollution in Minamata Bay, and dredging of mercury- and PCB-polluted bottom sediments in ports and harbours. While stringent effluent controls are still necessary, the critical situation of the past decades has generally improved.

Apart from these industrialized sites, the coastal waters remain relatively unpolluted and the environmental water quality standard is met for most areas. Coastal fisheries, recreational uses and nature conservation are still maintained in these areas. Of the total Japanese shoreline of 32,500 km, 56.7% remains natural and 13.9% semi-natural. About 64% of the natural coast has been designated as natural parks and nature conservation areas (Figure 9).

Figure 9: Protected area designations as percentage of natural coast



The baseline measures under the Water Pollution Control Law apply nationwide, and more stringent effluent standards can be adopted by local governments, where necessary, to control land-based wastewater discharges along the coast. However, illegal dumping of wastes along the shoreline, as well as pollution from ships (tar balls, accidental oil spills, etc.) still cause local threats in coastal areas.

Open seas

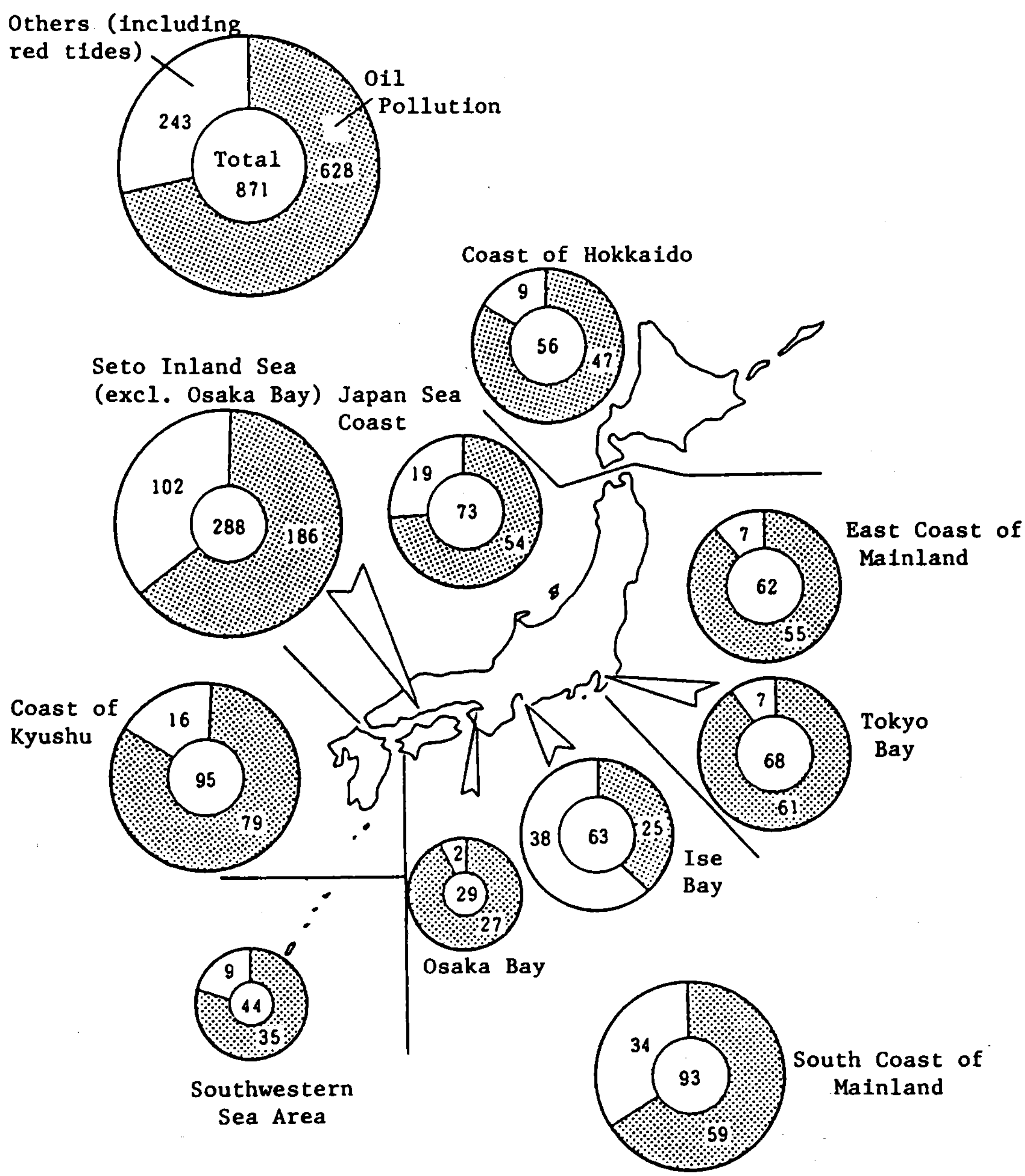
Two ocean currents, the Kuroshio and the Oyashio, flow by the Japanese islands. The pristine water quality of these currents is well known. Although there are some possibilities of long-range transport of land-based pollution, the main causes of pollution on the high seas are related to navigating ships and the dumping of land-based wastes. There were 871 marine pollution incidents identified by the Japanese Maritime Safety Agency in 1985, of which 72% (628 cases) were due to oil pollution. About half of the oil pollution incidents were in bays and the Seto Inland Sea, and the rest in the open sea or coastal waters (Figure 10).

Pollution related to marine transportation can only be controlled effectively through internationally co-ordinated efforts. Japan has thus closely followed the evolution of international agreement and conventions, and contributed to the related activities of the International Maritime Organization (IMO). Following the first convention in 1954 regarding oil pollution, international control of marine pollution related to ships has gradually strengthened and gained in scope. The most recent regulations are stipulated by the MARPOL73/78 Convention adopted in 1978, which covers the prevention of pollution by:

a. oil,
b. noxious liquid substances in bulk,
c. harmful substances carried by sea in packaged forms, or in freight containers, portable tanks or road and rail tank wagons,
d. sewage from ships, and
e. garbage from ships.

Of these, control of oil pollution and noxious liquid substance control are in effect.

Figure 10: Number of marine pollution incidents in 1985 by sea areas (as confirmed by the Maritime Safety Agency)



In accordance with the evolution of international conventions, Japan has strengthened its domestic laws to implement them. The Law relating to the Prevention of Marine Pollution and Maritime Disaster, as amended in 1983-1986, came into full compliance with the MARPOL Convention, implementing the oil and noxious liquid substances controls and preparing for the entry into force of other regulations. It also provides for the control of sewage and garbage from ships pending the entry into force of the respective MARPOL Convention regulations.

The ocean dumping of land-based wastes is also controlled by this law, which implements the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention).

The control of pollution by noxious liquid substances in bulk (MARPOL 73/78 Annex II) came into effect in Japan in April 1987. Chemical tankers and other vessels carrying noxious liquid substances in bulk (531 substances as of 31 July 1987) are subject to stringent regulations regarding operational discharge of these substances, pollution control equipment, ship types, etc. Carriage of substances whose pollution hazards have not been classified by the authority is subject to a notification and assessment procedure.

Since the early 1970's, government ministries and agencies have been monitoring marine pollution in the open seas. The Environment Agency conducts surveys along lines from the coast to offshore dumping areas ("A" areas, Figure 11), measuring the concentrations of heavy metals in sea water and bottom sediments, as well as general oceanographic observations. Surveys are also conducted by the Maritime Safety Agency to collect basic data for marine environmental conservation. The agency surveyed the waters around Japan, its major bays and the "A" areas for oil, PCBs and heavy metal concentrations in sea water and bottom sediments. No increase in pollution was found in any of the areas surveyed.

Regular surveys are made of tar balls drifting in the waters around Japan or washing up on the coast. The results of the 1985 surveys showed that the number of tar balls adrift or washed ashore at fixed observation points has decreased over the last several years.

Future prospects

While most marine pollution sources, both land-based and at sea, have been controlled, continuing efforts are needed to prevent marine pollution in and around Japanese waters. A broad international framework for the protection and preservation of the marine environment, addressing all these pollution sources, has been included in the United Nations Convention on the Law of the Sea (Part XII). As this convention is now in the process of entering into force, the international exchange of information and review of experience on controlling marine pollution among the countries in the Pacific region would be particularly useful.

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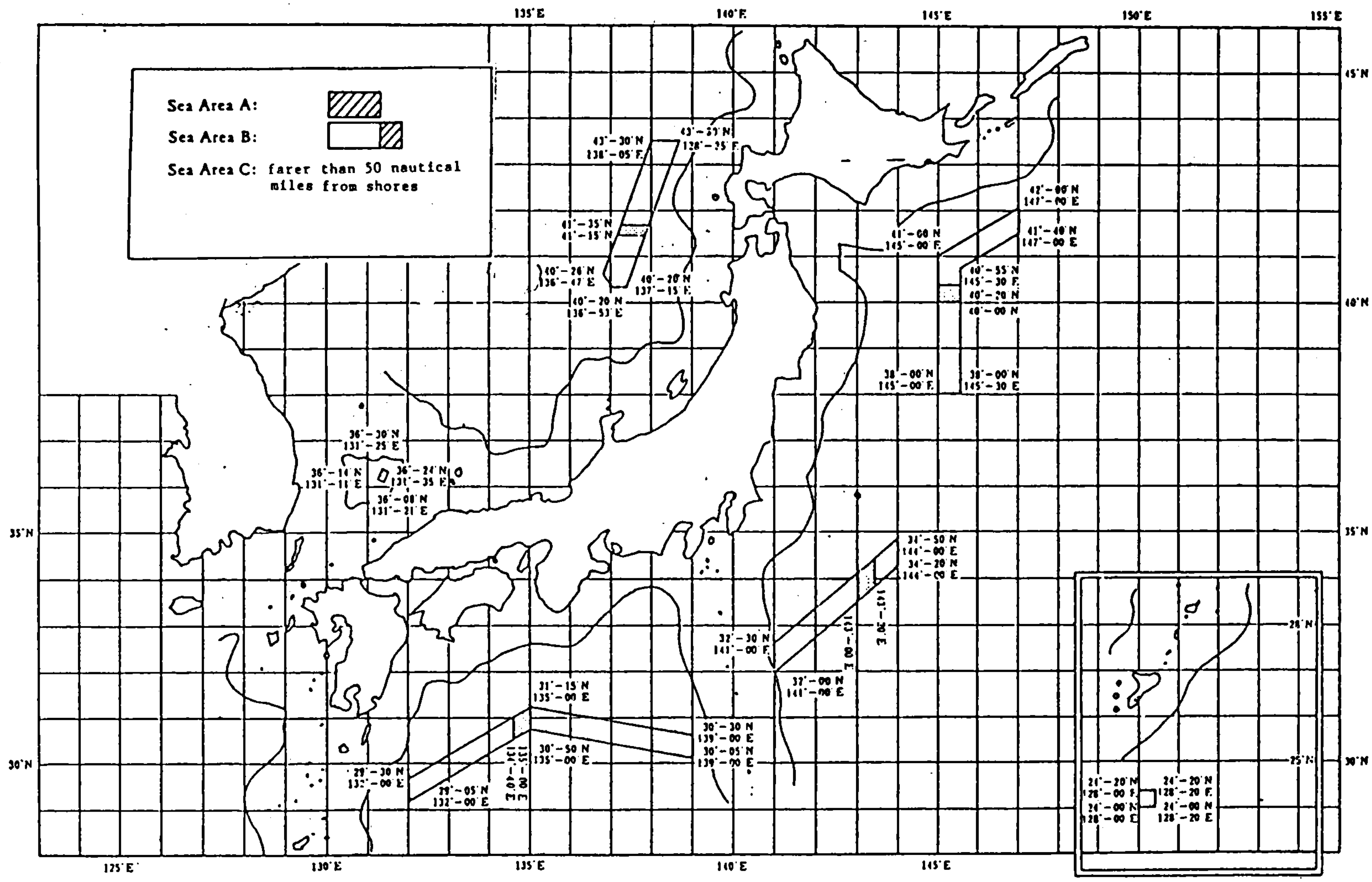
Figure 11: Zones for ocean dumping off the coast of Japan



MARINE POLLUTION RESEARCH AND MONITORING IN KOREA

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ABSTRACT

It is essential to protect the water quality of coastal areas for the maximum utilization of Korea's abundant marine resources. However, the transport of pollutants into coastal waters has been increasing due to high industrialization and urbanization during the last three decades in Korea.

This paper summarizes the major inputs of pollutants into Korean coastal waters and the various organizations and their coastal pollution research and monitoring programmes. These organizations include government agencies, research institutes and many universities. Some problems for future research are discussed, along with the need for regional co-operation in marine pollution research and monitoring among neighboring countries.

Introduction

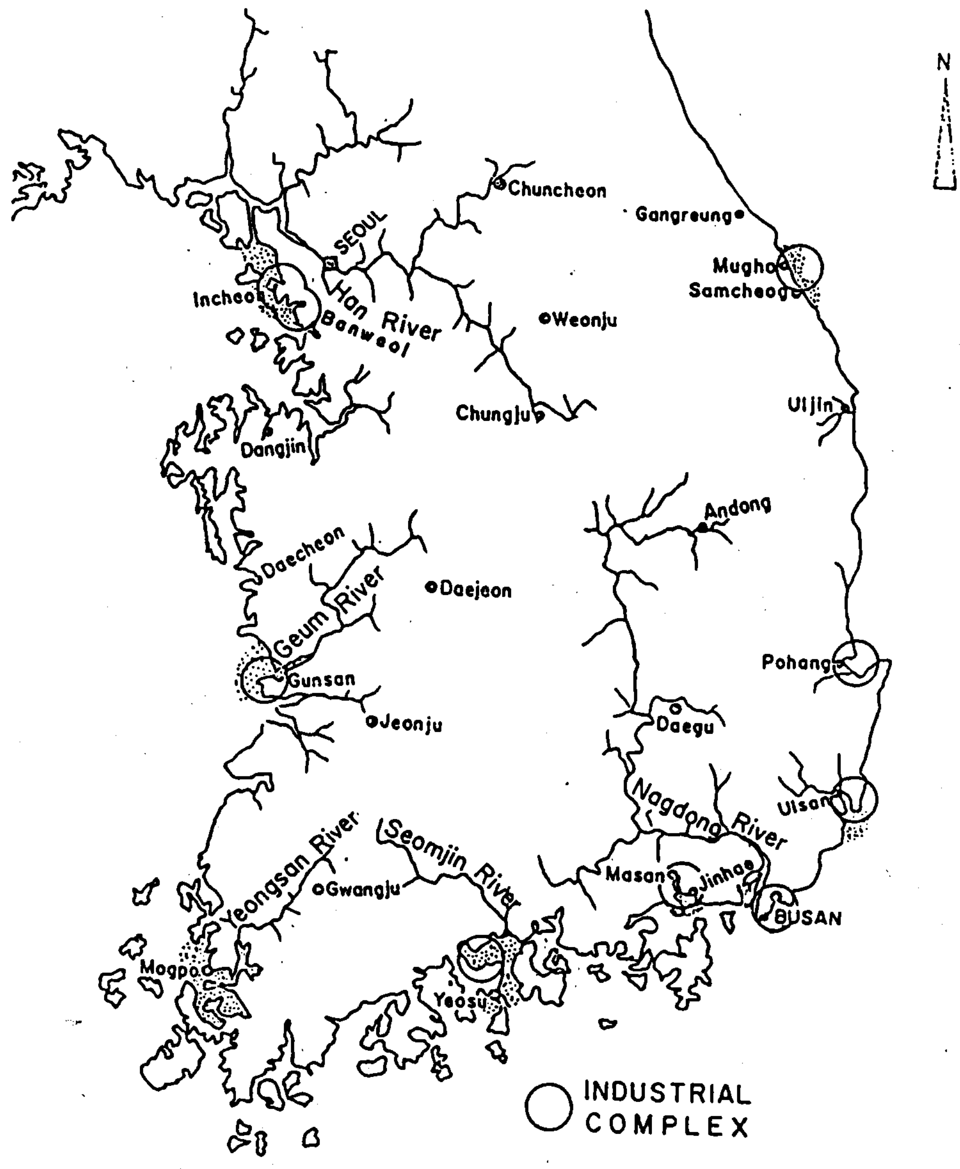
Korea is a peninsula with limited land resources, and as such its future economic development depends to a great extent on the use of marine resources. For the maximum utilization of these resources, it is necessary to protect the quality of Korea's coastal waters. However, during the last three decades high industrialization and urbanization have caused a rapid increase in the transport of pollutants into the coastal waters of Korea. In addition, many industrial complexes have been established along the coast because of the ease of transportation, water supply and waste disposal. The major coastal industrial complexes are shown in Figure 1.

The southern and western coastal areas of Korea are especially susceptible to water pollution. The coastlines are long with many bays and thousands of small nearby islands. The depth is relatively shallow. These geographical conditions make for a long residence time for coastal water in many bays, so that they are easily polluted by small quantities of pollutants, and once polluted they remain so for an extended period. The eastern coastline, on the other hand, is relatively smooth, with a bottom sloping rapidly to considerable depths. It is thus relatively less susceptible to water pollution except for some bays near the industrial complexes.

The shallow depths and long coastline of the western and southern coasts provide optimum sites for aquaculture, which has developed rapidly since the proclamation of 200-mile economic zones by many countries. The Environmental Administration has designated most of the southern coast as "Clean Coastal Areas" set aside for aquaculture.

Institutional arrangements for environmental protection in Korea are based on the new Environmental Protection Law and the Marine Pollution Control Law enacted in 1978. The Environment Administration was established in 1980 in the Ministry of Health and Social Affairs.

Figure 1: Coastal industrial complexes in Korea



Monitoring strategies and priority pollutants

The monitoring system involves the selection of proper monitoring stations, which include those in coastal areas susceptible to pollution as well as clean areas as baseline stations. The frequency of sampling, type of samples (water, sediments or biological organisms) and the pollutants monitored depend upon the area and the objectives of the monitoring, as well as upon the available manpower and budget.

Indicator organisms for pollution are sampled and analysed for toxic pollutants. Monitoring of molluscs such as mussels or oysters, as in the Mussel Watch (Goldberg, 1978), can be useful for identifying "hot spots" and for comparisons on a global basis.

The priority pollutants monitored in Korea are:

- organic loading (COD),
- nutrients (nitrogen compounds, phosphates and silica),
- heavy metals (Cd, Cu, Pb, Hg, Ni and Zn),
- chlorinated hydrocarbons (PCB and DDT) and pesticides,
- some radioactive substances, and
- thermal pollution.

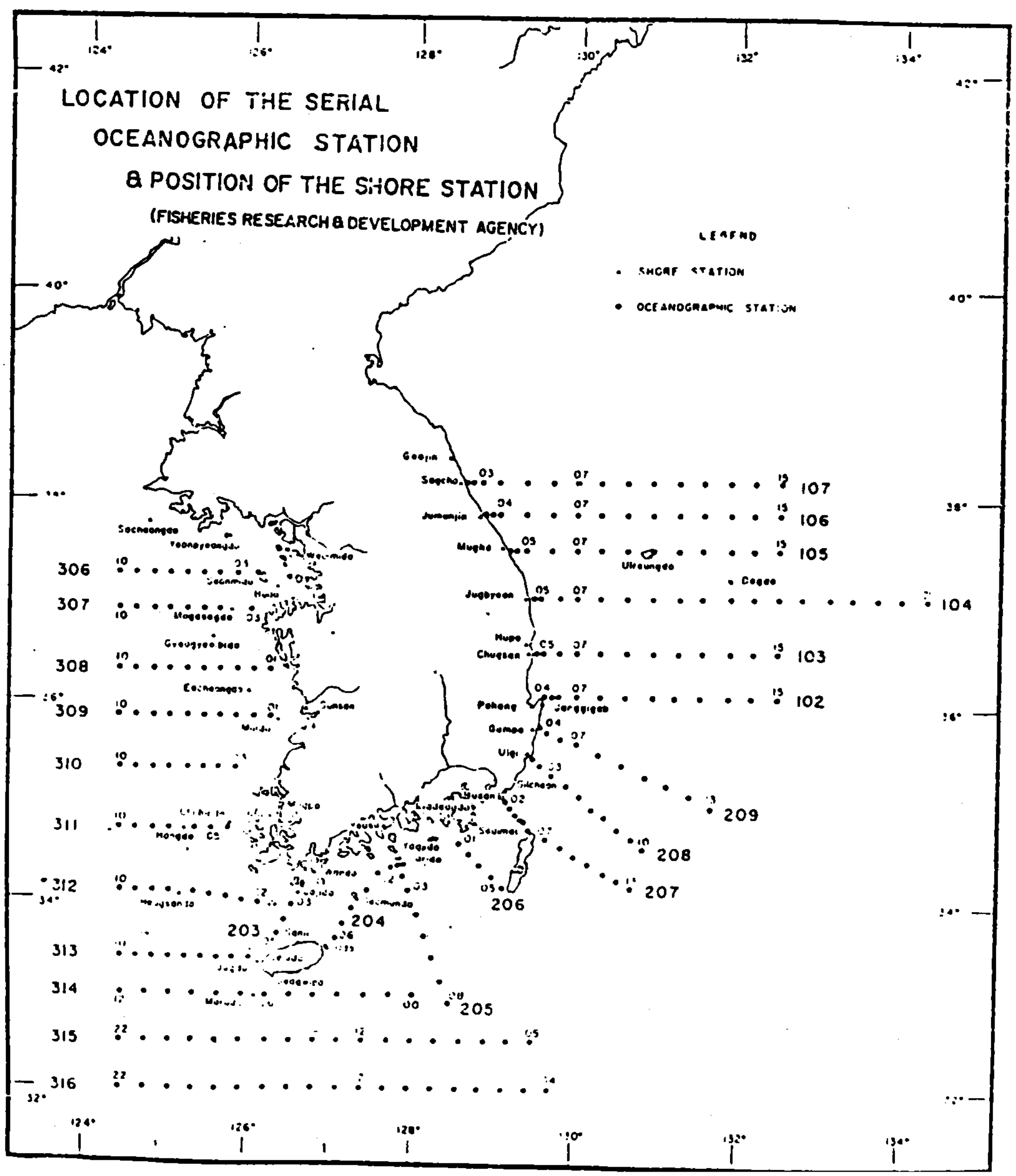
Monitoring organizations and their programmes

Korean organizations which monitor pollutant transport and pollution of the marine environment include government agencies, research institutes and many universities. These are:

- Fisheries Research and Development Agency (FRDA)
- Hydrographic Office, Ministry of Transport (HOMT)
- Korea Ocean Research and Development Institute (KORDI)
- Environmental Administration and National Environmental Protection Institute (NEPI)
- Coast Guard, Ministry of Interior
- various universities and other research institutes.

The Fisheries Research and Development Agency (FRDA), under the Fisheries Administration of the Ministry of Agriculture and Fisheries, has been conducting research on fisheries development since 1921. The FRDA started monitoring marine pollution in 1952 at their serial oceanographic stations (Figure 2) and in other coastal areas where fishery damage has been reported or suspected (FRDA, 1925-1986).

Figure 2: Monitoring stations of the FRDA

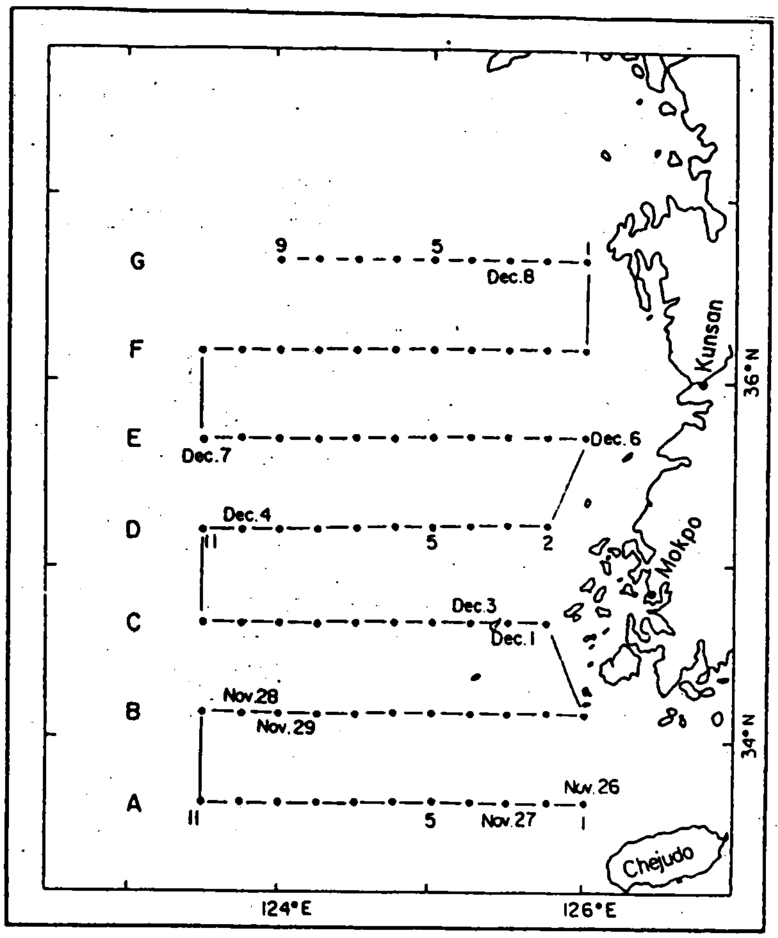


Since 1970, the FRDA has taken samples of seawater, sediments and marine organisms bi-monthly from 350 coastal stations and analysed them for COD, nutrients, petroleum hydrocarbons and heavy metals. The FRDA has also participated in the Mussel Watch since 1981, taking seasonal samples of mussels and oysters from aquaculture areas and other areas vulnerable to pollution for trace metal analysis.

The Hydrographic Office under the Ministry of Transportation (HOMT) has since 1960 made oceanographic observations at serial stations similar to those of the FRDA. The HOMT measures tides, sea levels and currents, and performs some chemical analyses (HOMT, 1953-1986).

The Korea Ocean Research and Development Institute (KORDI) has conducted environmental research in the coastal waters near the industrial complexes and nuclear power plants. Beginning in 1982, KORDI has made physical, chemical, biological and geological observations seasonally in the Yellow Sea at the stations shown in Figure 3. It has also participated in the Mussel Watch since 1987 (KORDI, 1983-1986).

Figure 3: The Yellow Sea monitoring stations of KORDI



The Environmental Administration and its six regional offices have carried out pollution monitoring at 179 coastal stations throughout the country since 1985, and the National Environmental Protection Institute (NEPI) has sampled various shellfish for trace metal analysis since 1986.

The Coast Guard under the Ministry of the Interior is involved in pollution monitoring of petroleum hydrocarbons at 100 coastal stations.

Other research institutes and many universities including Pusan National Fisheries University are engaged in various pollution monitoring activities on an irregular basis, with funding from government agencies and private industries.

Present status and future directions

Since the 1960's, damage to fisheries and aquaculture by wastewater discharges has been reported near the coastal industrial complexes. This damage has mainly been due to red tides, a symptom of eutrophication. There have been no reports of heavy metal pollution effects in any coastal areas.

To control the problem, treatment plants for both municipal and industrial wastewater are nearing completion at the coastal industrial complexes, and others are planned to be built within the next five years at the major cities throughout the country. The Environmental Administration was tripled in size in 1986, and implementation and enforcement of effluent standards for various industries have been greatly enhanced. Since 1985, environmental impact statements are also required for major national projects including land reclamation in the coastal zone.

Since various government agencies, research institutes and universities are monitoring marine pollution for different pollutants and for different reasons, there needs to be better co-operation and co-ordination among these agencies in the future so that the limited manpower and budgets can be pooled for systematic monitoring.

Indicator organisms have an advantage over seawater samples in that they integrate pollution levels over long periods of time. Studies are needed of the fate of pollutants in coastal waters, of ecological impacts of pollution, and of the bioaccumulation of toxic substances, so that ecosystem models can be constructed to provide a predictive capability for the impact of any environmental changes or development.

Need for regional co-operation in marine pollution monitoring

Since marine pollution knows no boundaries and its monitoring requires manpower, research vessels and large budgets, there is a need for concerted monitoring efforts by many countries. Co-operative programmes are needed for the exchange of data and information, the exchange of scientists, intercalibration of analytical techniques, and joint and split sampling. These programmes can be developed step by step, and will contribute to the protection of the water quality of the global marine environment.

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DISTRIBUTION OF HEAVY METALS IN KOREAN COASTAL WATERS

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ABSTRACT

Concentrations of cadmium, copper, lead, and zinc have been measured in more than 300 surface water samples collected from Korean coastal waters. They are compared with values in other regional seas in an attempt to assess the heavy metal contamination of the study area.

In the south-eastern Yellow Sea, all four metal levels vary greatly within short distances. Cadmium and copper showed similar spatial distributions: low in high salinity oceanic waters in the south-eastern area, and high in low salinity shelf waters in the north-western area. Lead and zinc distributions are much alike but differ from cadmium and copper; they are high in the south-west and low in the south-east and north-west areas. Extremely high lead and zinc levels in the south-western area are of particulate origin. It appears that cadmium and copper levels in the Yellow Sea shelf waters are as high as those of the North Sea or the Baltic. The elevated metal concentrations in the Yellow Sea shelf waters appear to be of continental origin, but their source, if anthropogenic or natural, is yet to be identified.

Despite large metal inputs to Ulsan and Masan Bays, the metal levels are not very high. The present study reveals metal concentrations several times to orders of magnitude lower than previous ones; this conceivably stems from experimental artifacts including analytical errors in the previous studies rather than from environmental improvement.

Introduction

Korean coastal waters, including the Yellow Sea in the west, the northern South China Sea in the south, and the East Sea to the east of Korea, have been receiving large quantities of municipal and industrial wastes from their surrounding continental land areas. The amount of wastes entering these waters is increasing rapidly due to the fast growing industrialization and urbanization of the neighboring countries: Korea, China and Japan. In addition, about 20% of the world's population, or one billion people, are concentrated in this region and ultimately discharge all their wastes into these waters. The study area has unfavourable natural conditions for the receipt of such a large pollution burden. Water depths are very shallow except in the East Sea. The exchange of nearshore water with the open sea is restricted by the complicated coastline and the presence of numerous islands.

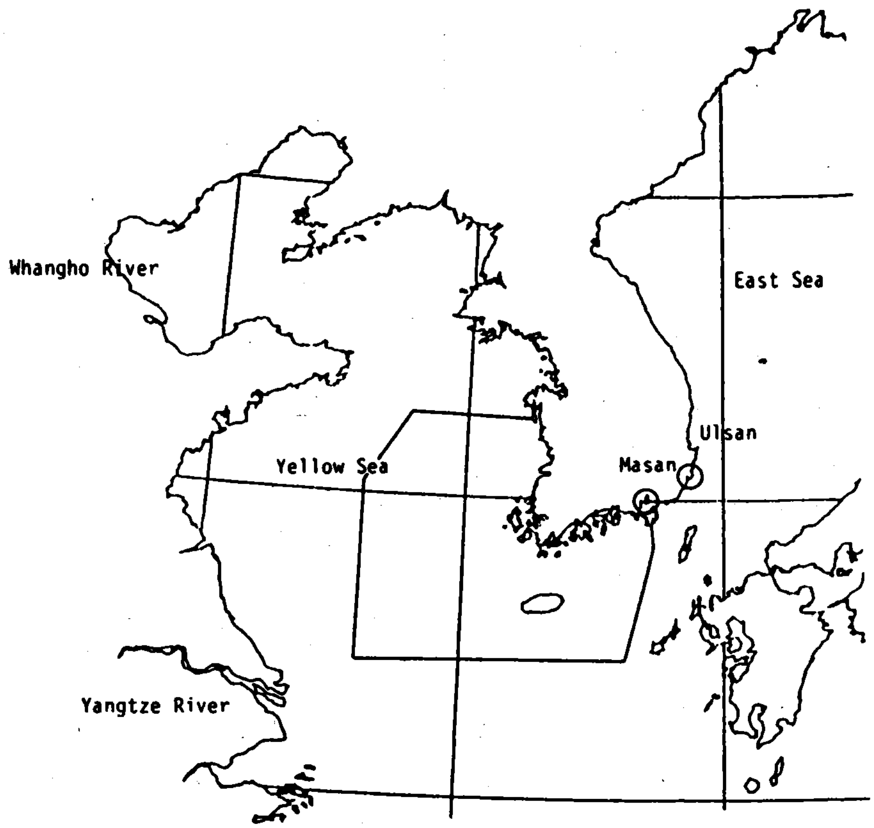
At the same time, there are strong demands to protect these waters from pollution since they provide the neighboring countries with extensive natural resources, particularly living resources. For instance, Korea relies on marine fisheries for 10% of its food resources, and China and Japan also depend heavily on these waters for their coastal fisheries.

Despite the paramount importance of protecting these waters from pollution, the background information on priority pollutants such as heavy metals, chlorinated hydrocarbons and radionuclides is virtually lacking. In an effort to get environmental baseline data, we sampled at over 100 stations in the south-eastern Yellow Sea. The initial results for heavy metals in surface waters are reported herein. In addition, the results for two heavily polluted small bays, Masan and Ulsan Bays, are also presented.

Sampling and analytical procedures

The surface water sampling locations are shown in Figures 1, 9 and 11. Seventy-seven sampling stations were occupied in the south-eastern Yellow Sea during two separate cruises in February and November 1986.

Figure 1: Location of the study areas



Surface water samples were collected while the ship was moving slowly (2 knots per hour) using precleaned polyethylene bottles hung on a PVC pole extended over the side of the ship (Boyle et al., 1981). The samples collected near shore where suspended solids are high were filtered through 0.4 µm Nucleopore filters which had been soaked in dilute acid for several days. Filtration was performed under a class-100 laminar flow bench within 12 hours after sampling. All samples were stored in pre-cleaned high density polyethylene bottles after acidification by adding 4 ml of 6N Teflon-distilled HCl per litre of seawater. The results obtained were defined as dissolved and acid soluble metals for filtered and unfiltered water, respectively.

Heavy metal concentrations (Cd, Cu, Pb, and Zn) were determined by flameless atomic absorption spectrometry following a 50:1 preconcentration using a dithiocarbamate extraction method. Analytical accuracy and precision were around 2 to 8%. The accuracy of the method was tested through participating in several intercalibration exercises and analysing standard spiked seawater. A strict quality control programme was developed and utilized throughout the analyses. Details of the method will be published elsewhere.

Results and discussion

South-eastern Yellow Sea

Analytical results for cadmium, copper, lead, zinc and salinity from two separate cruises are depicted in Figures 2, 3, 4, 5, and 6 respectively. Since the samples were not filtered and stored for several months after acidification, the metal concentrations can be defined as acid soluble. Lead data from the February cruise are not included since we encountered severe lead signal suppression by chloride which was inadvertently introduced during solvent extraction. This problem was solved before the analysis of the November samples by employing an additional step involving washing the Freon fraction with distilled water.

Figure 2: Surface cadmium levels in the south-eastern Yellow Sea February and November 1986 (µg/l)

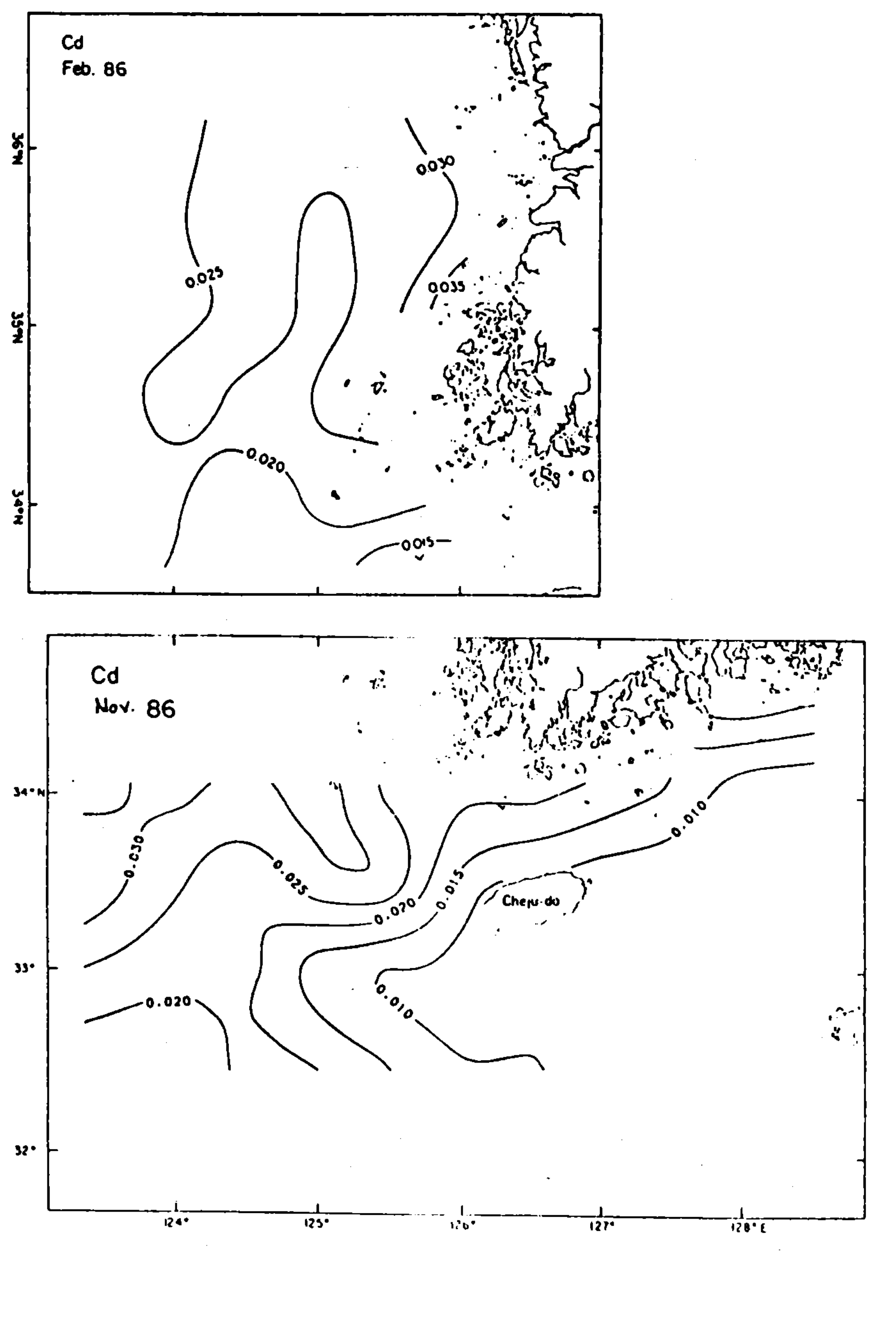


Figure 3: Surface copper levels in the south-eastern Yellow Sea
February and November 1986
(µg/l)

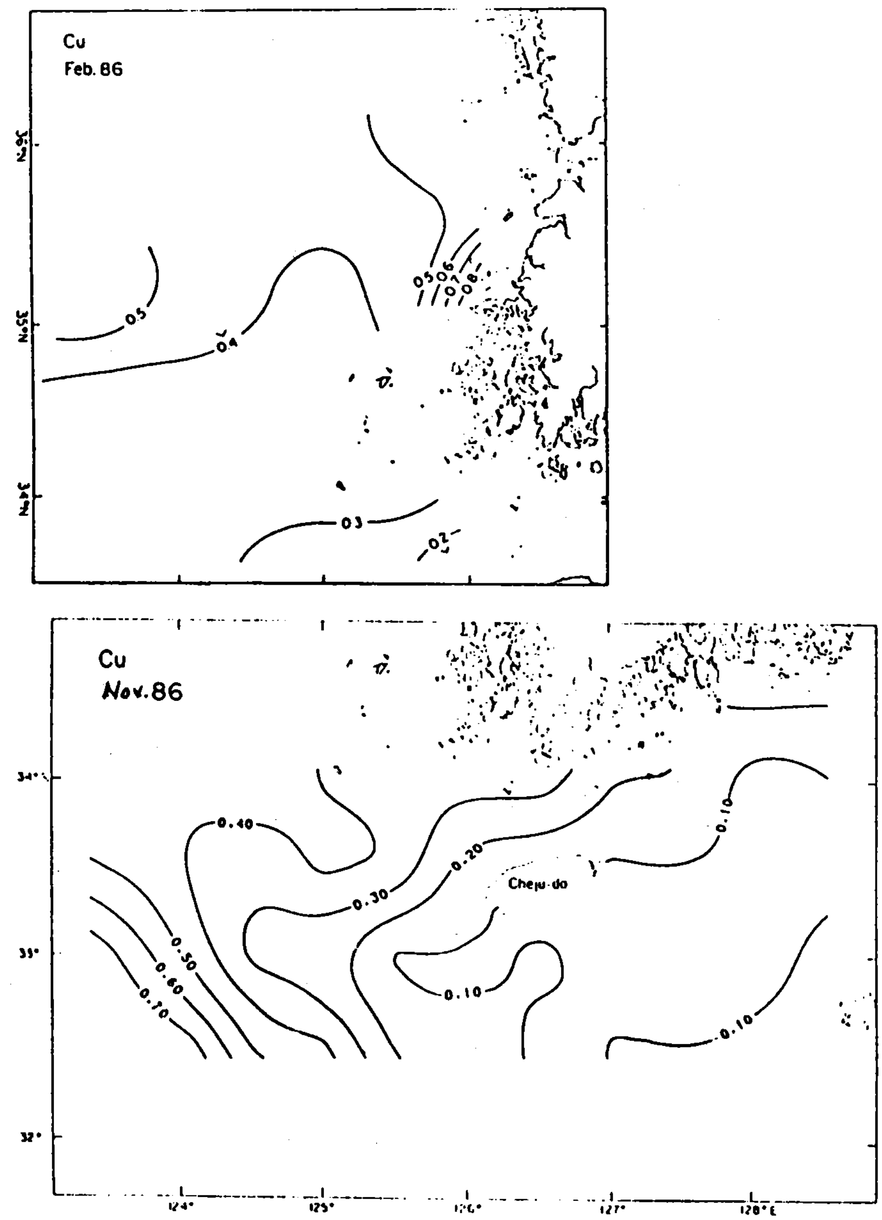
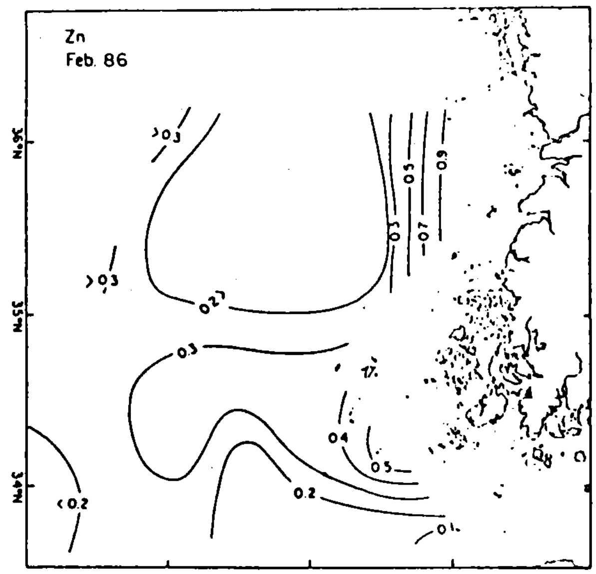


Figure 4: Surface zinc levels in the south-eastern Yellow Sea February and November 1986 (µg/l)



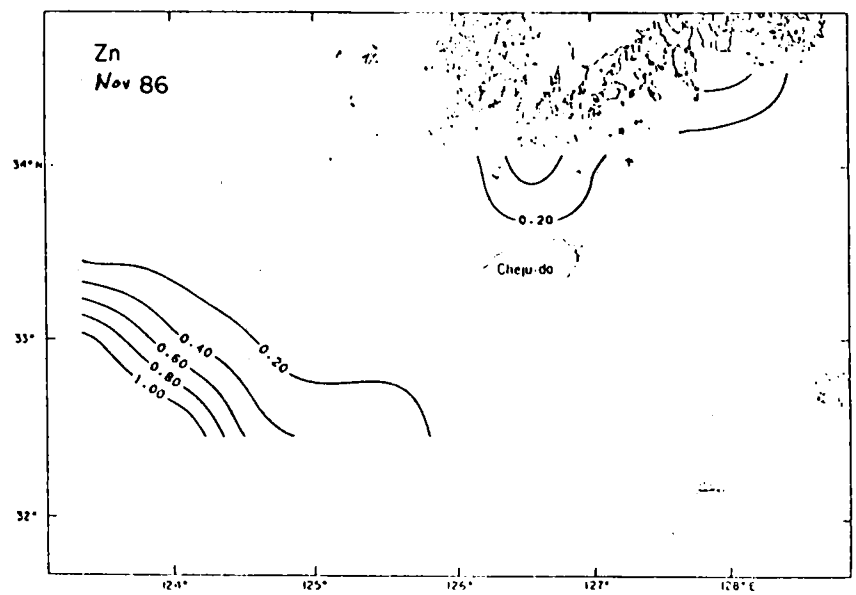


Figure 5: Surface lead levels in the south-eastern Yellow Sea, November 1986 (µg/l)

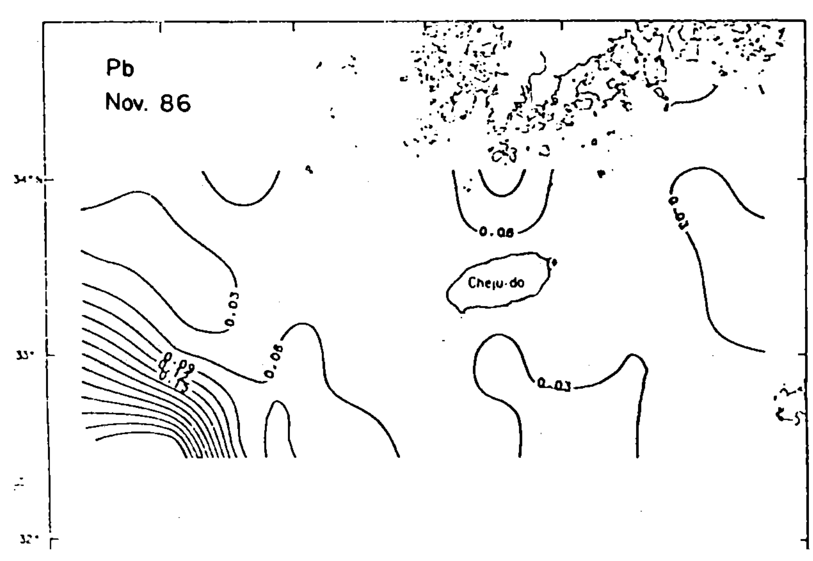
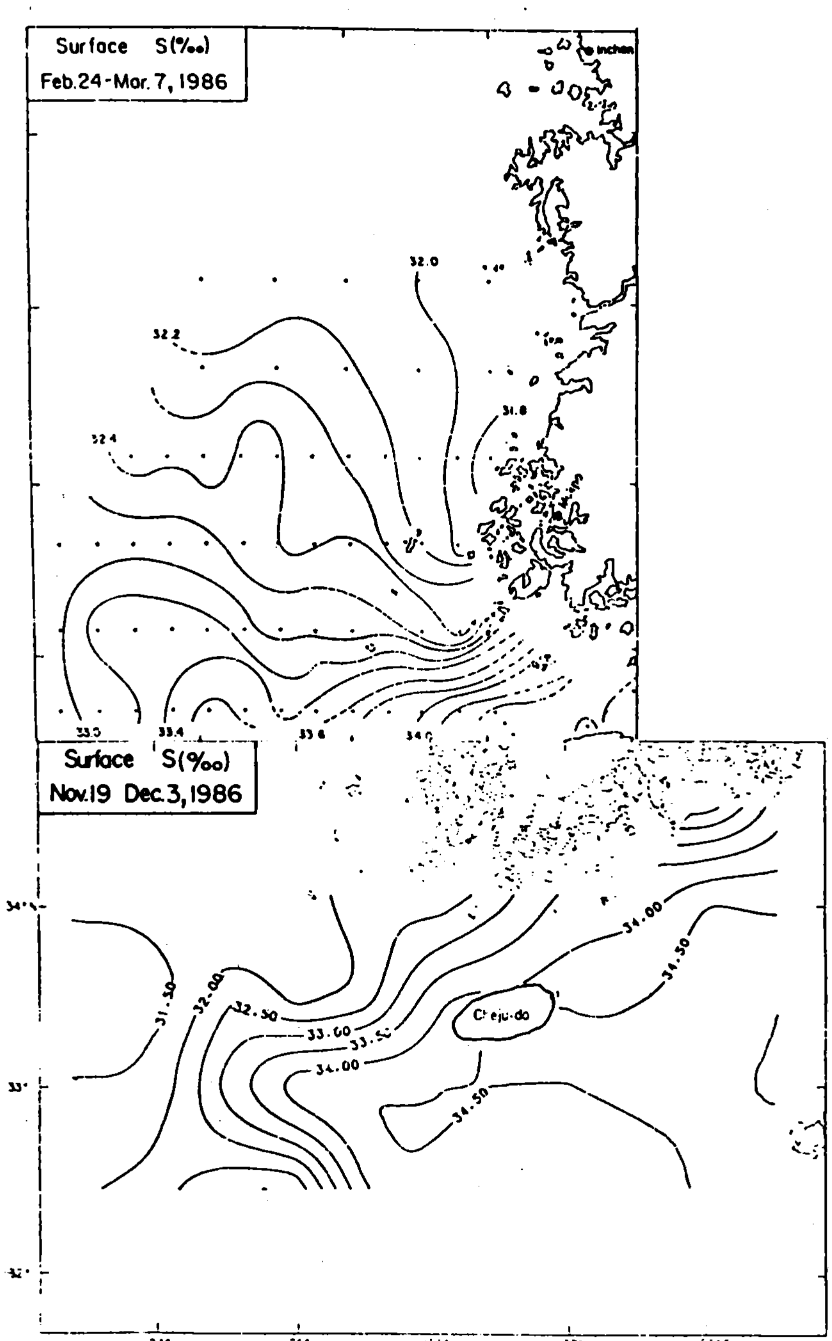
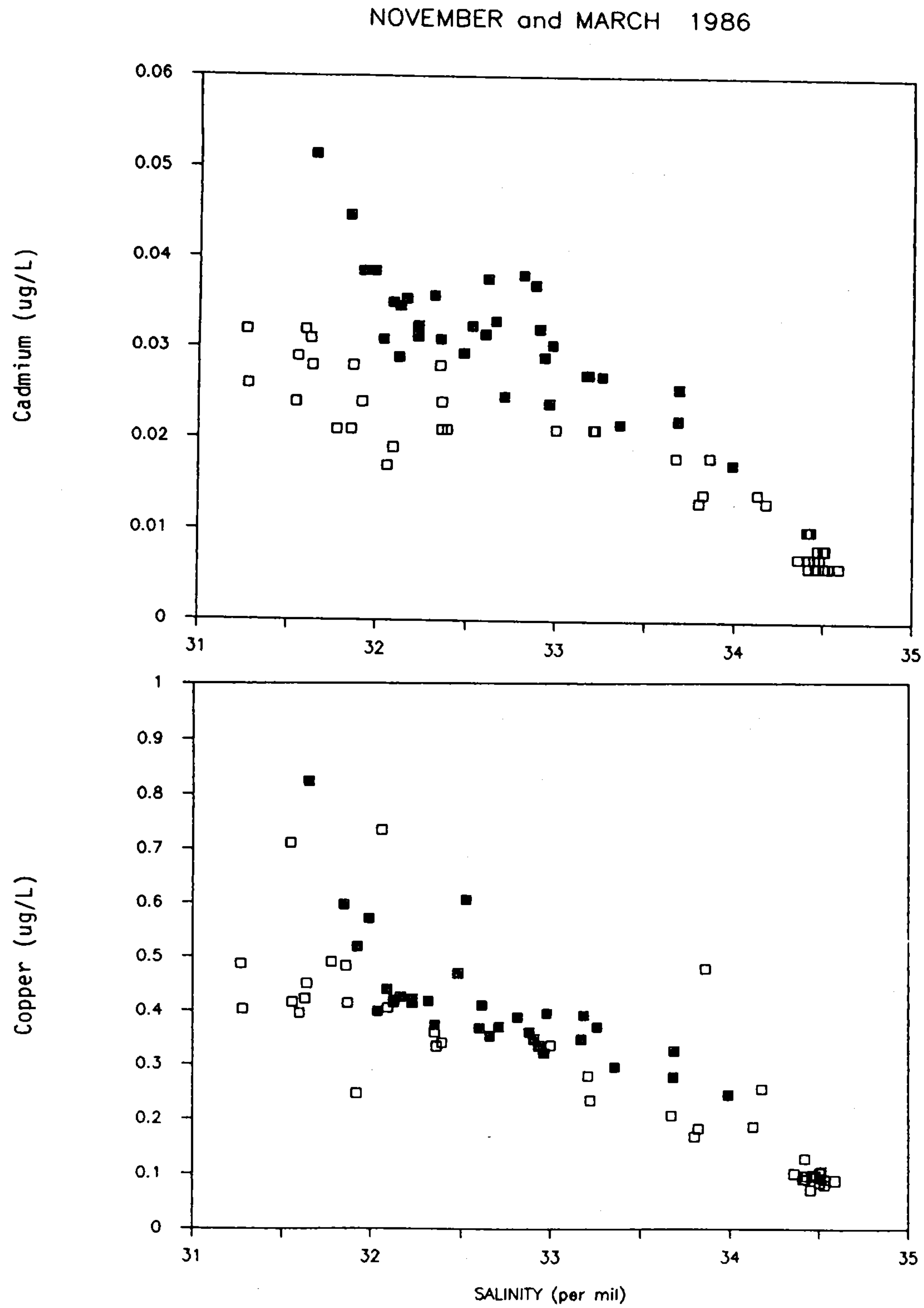


Figure 6: Surface salinity levels in the south-eastern Yellow Sea, February and November 1986 (parts per thousand)



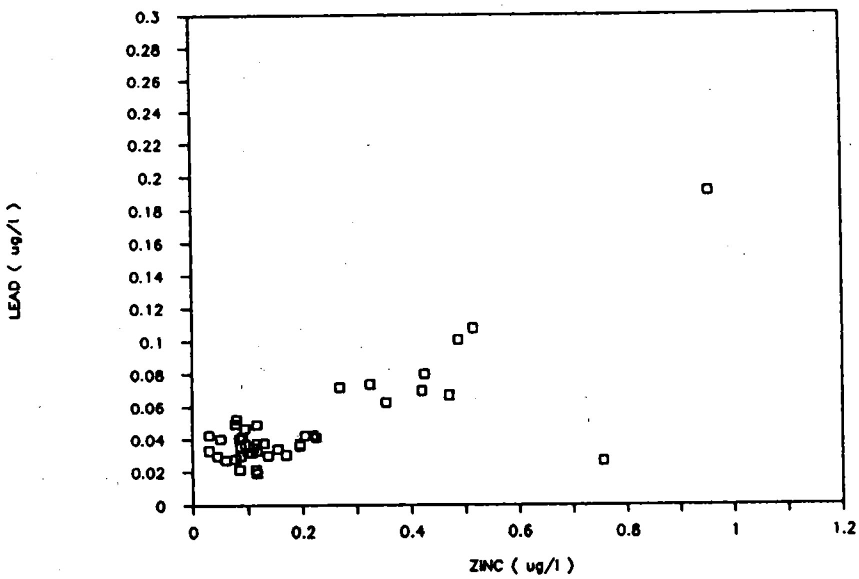
As shown in the figures, all four metals show large concentration variations between stations. Cadmium and copper reveal similar spatial distribution patterns: low in the south-eastern high salinity oceanic waters and high in the north-eastern low salinity shelf waters. There are strong inverse correlations between salinity and cadmium or copper (Figure 7), indicating their continental origin and conservative nature within the salinity range. There are a few copper values which deviate significantly from the linear relationship and these probably originated from particulate copper in suspended matter. These samples also showed high iron, lead and zinc contents indicative of high suspended matter.

Figure 7: Correlation of cadmium and copper with salinity



The distributions of lead and zinc are very much alike, and differ from those of cadmium or copper. Extremely high lead and zinc concentrations in the south-west and north-east regions must come from high suspended matter. There is a strong positive correlation between these two metals (Figure 8) and their similar abundance ratio (Zn/Pb:50) to that of nearshore sediment supports the particulate nature of these metals.

Figure 8: Positive correlation between lead and zinc (Nov. 1986)



For purposes of inter-regional comparison, the average concentrations and ranges of the four metals are summarized in Table 1 along with those of other sea regions. All four metal levels in the south-eastern Yellow Sea appear to be relatively high, almost as high as those of the Baltic and North Seas which are typical of heavy metal polluted seas or at least of those where pollution is suspected. The elevated cadmium and copper in the shelf water could originate from either the continent or deep water. However, latter appears not the case in this area as an inverse correlation with salinity was observed. Both copper and cadmium have close negative correlations with salinity, indicative of a freshwater origin for both metals. The copper and cadmium concentrations extrapolated to zero salinity (Cu 4.4 µg/l and Cd 0.2 µg/l) are substantially higher than those of the Yangtze River water (Cu 1.3 µg/l and Cd <0.001 µg/l) (Edmond et al., 1983). The Yangtze River is the biggest river flowing into the Yellow Sea, and it discharges more than all the others combined. Other sources are therefore needed to explain the elevated copper and cadmium concentrations.

Ulsan Bay

Ulsan Bay is a small embayment located on the south-east coast of the Korean peninsula, into which flow two small rivers, the Taewha and Oewhang (Figure 9). The Bay is open to the East Sea with a steeply sloping bottom so that the bay water readily mixes with the ocean water of the East Sea. Because of the rapid industrialization and urbanization of Ulsan city since the mid-1960's, this bay receives large quantities of various kinds of municipal and industrial wastes from its surroundings and is probably the most polluted bay in Korea.

Among various potential pollutants, heavy metals are of particular concern, especially in Onsan Bay where most wastes from the Onsan nonferrous industrial complex flow in. Heavy metal pollution drew special public attention in 1984 when Onsan residents developed an unidentified disease. Some scientists maintained that the disease was cadmium poisoning based on its symptoms which were similar to those of cadmium poisoning. However, they found no direct evidence for this, and it was finally concluded after detailed investigations that the disease was not related to cadmium poisoning. Nevertheless the whole village has been evacuated at a cost of over US$ 150 million.

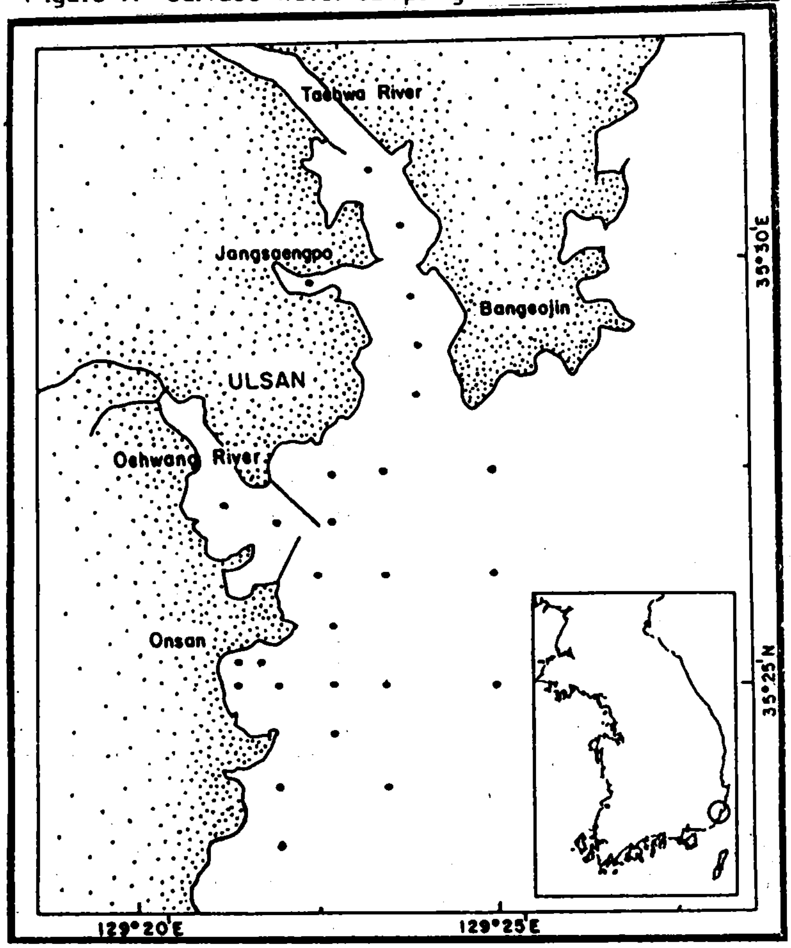
Table 1: Heavy metal concentrations in various regions
(range, with mean in parentheses)

Area	Cd(ng/l)	Cu(ng/l)	Pb(ng/l)	Zn(μg/l)	Metal state	Reference
South-East Yellow Sea	6-32 (17)	79- 725 (263)	19-201 (50)	0.03-0.96 (0.20)	total	this study
	17-45 (31)	245- 607 (400)		0.11-0.93 (0.28)	total	this study
North Sea	10-25	150- 600			dissolved	Kremling (1983)
	10-60	125- 665	30-265		total	Balls (1985)
	21-53 (34)	104- 536 (288)	38-289 (125)		total	Mart & Nurnberg (1986)
	13-31 (25)	111-1450	21- 60	0.21-0.90	total	Danielsson et al. (1985); Brugmann et al. (1985)
Baltic Sea	30-50	600-1000	50-200	1.5-3.5	total	Magnusson & Westerlund (1980)
	60-70	300- 900	100-200	3.0-3.5		Koroleff (1980)
	30-50	400-1200	100-200			Gustavsson (1981)
Mediterranean Sea	5-10 (8)	70- 120 (98)	30- 40		?	Laumond et al. (1984)
	6-11	120- 180			total	Spivack et al. (1983)
	7-10	50- 150			total	Copin-Montegut et al. (1986)
Gulf of Mexico	1- 8	60- 180			total	Boyle et al. (1981)
Tokyo Bay	6-12	200- 600	40-100		total	Hirao et al. (1983)
Open ocean	0.2	0.04	20	0.003		Bruland (1983)

Table 2: Summary of previous heavy metal determinations in Ulsan Bay
(range, with mean in parentheses)

Year	Cd(μg/l)	Cu(μg/l)	Pb(μg/l)	Zn(μg/l)	Metal state	Reference
1976	0.00-1.80 (0.21)	0.83-10.6 (1.30)	0.00- 4.53 (1.18)	0.0-21.8 (3.8)	total	Won et al. (1976)
1978	0.05-4.8 (0.76)	0.8 -14.1 (3.3)	4.0 -22 (11)	4.2-115 (18)	total	Lee et al. (1978)
1981	0.3 -2.0 (0.51)	0.99- 8.5 (3.0)	0.55- 2.91 (2.68)	12.1-38 (18.4)	total	Lee (1981)
	0.21-0.84 [0.47]	0.73- 5.86 [2.4]	0.13- 3.01 [0.89]	9.3-34 [15.7]	dissolved	
	0.3 -0.6 (0.4)	3.6 -46.1 (12.9)	2.7 - 6.7 (5.3)	12.3-182 (49)	total	NIER (1981)
1982	<0.1 -5.0 (0.5)	<0.1 -87 (3.9)		0.4-70 (7.7)	total	Park et al. (1982)
1984	<0.03-0.51 (0.08)	<0.03- 7.7 (2.1)	<0.05- 0.8 (0.14)	2.2-25.6 (7.6)	total	KEPA (1984)
1986	0.01-0.77 [0.037]	0.10-10.0 [0.78]	0.013-0.51 [0.048]	0.11-69 [2.82]	dissolved	this study

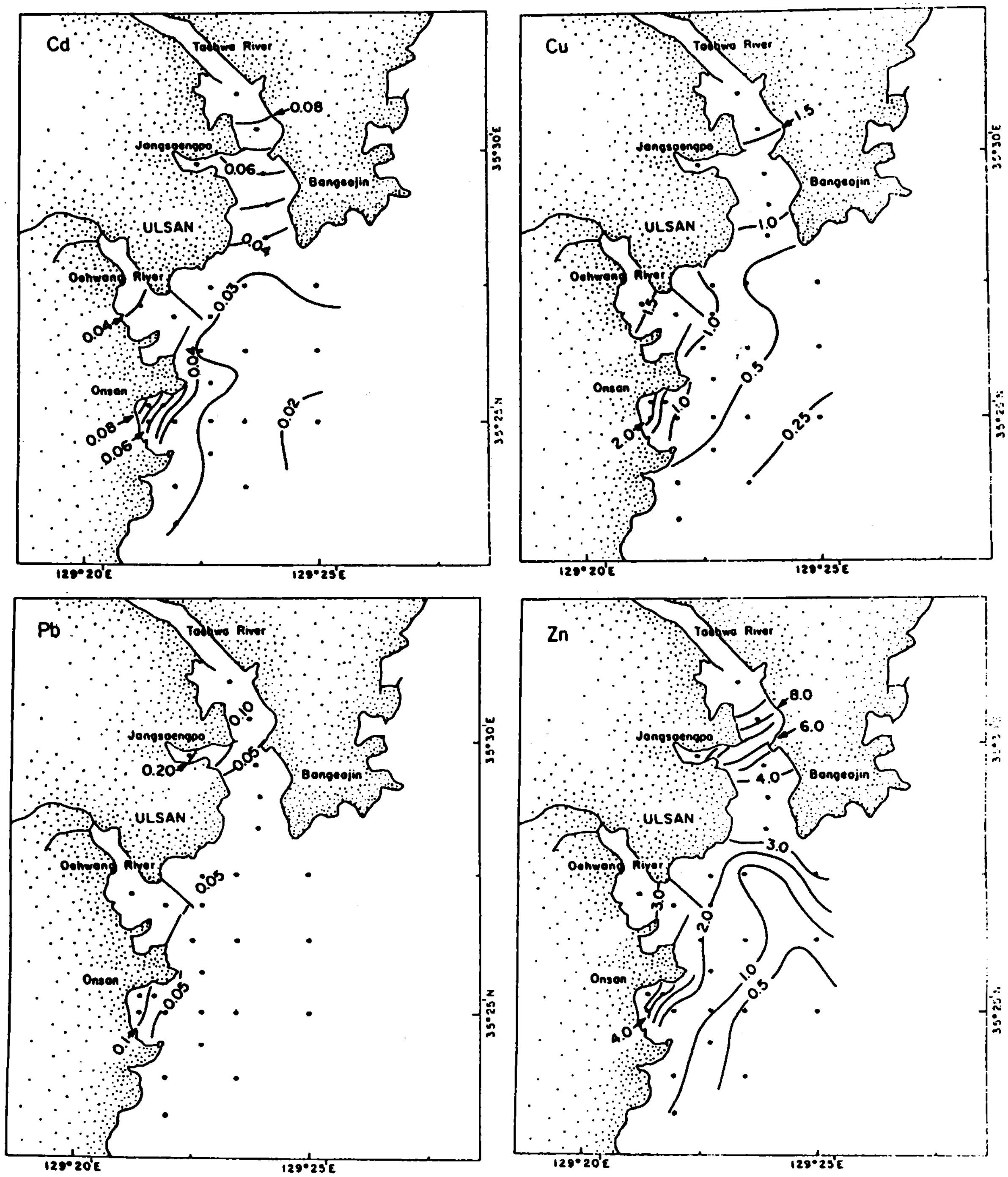
Figure 9: Surface water sampling stations in Ulsan Bay



The average concentrations and ranges of the four metals obtained in the present study are summarized in Table 2 along with those of previous studies. Yearly average concentrations of cadmium, copper, lead and zinc are shown in Figure 10. All metals showed elevated concentrations at nearshore stations, particularly those in Onsan Bay and the Taewha Estuary. Concentration differences between stations range from 4 for lead to more than 10 for cadmium and zinc. Generally, the highest concentration was observed in station 18 in Onsan Bay which receives substantial amounts of industrial wastes from the nonferrous industrial complex. Taewha Estuary also has elevated heavy metal levels, but the highest level generally occurs at station 2 or 4 rather than the innermost station 1, and this is probably due to another metal source near the area. There are a few large factories in the vicinity such as an automobile plant, a paint factory and a ship rehabilitation yard, which may discharge large quantities of heavy metal-containing wastes. The distribution of lead is quite different from that of the other metals in that the highest concentration occurs in station 3 and there are relatively small differences between stations. The first may be explainable by a difference in sources and the latter by the difference in the metal input pathway. Atmospherically transported pollutants tend to be more dispersed than water transported ones. The elevated lead level at station 3 may come from the nearby petrochemical complex.

In comparison with previous studies, the metal concentrations obtained in this study are much lower (Table 2). For cadmium and lead in particular the concentrations differ by more than ten times. One can argue that these are simply the differences between dissolved and total concentrations (dissolved metals were determined in this study as opposed to total or acid-soluble metals in most previous work). That may be partly true for the metals which are abundant in crustal materials such as lead and zinc, but it is not true for cadmium and copper which exist primarily in dissolved states. There is one previous study in which both dissolved and total metals were measured and no substantial differences were found between them.

Figure 10: Spatial distributions of dissolved cadmium, copper, lead and zinc in Ulsan Bay surface waters



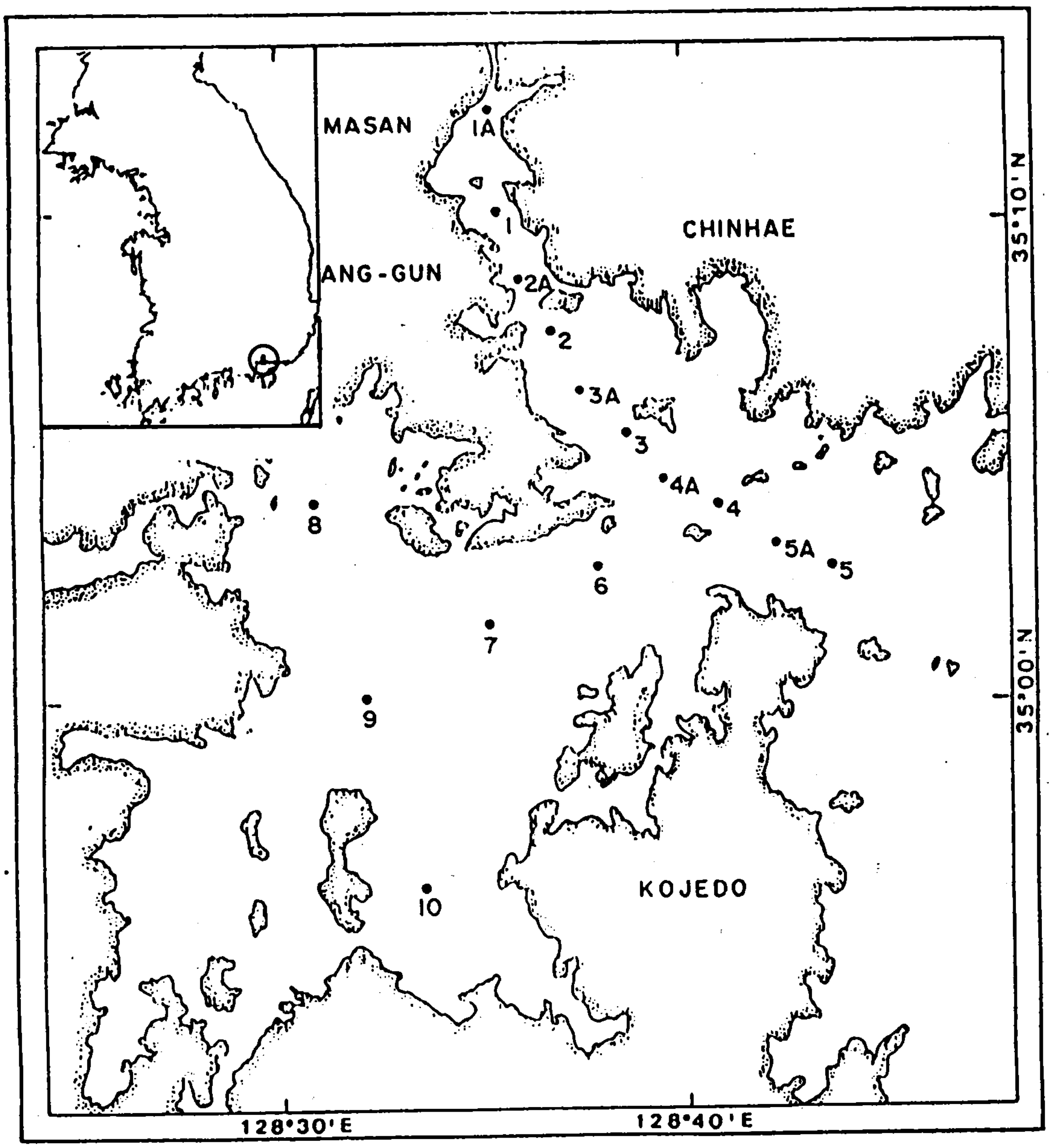
Another possible cause of the differences could be an environmental improvement in the bay waters. However, this is also unlikely since no particular measures to control marine pollution have been taken over the last ten years while the pollution load must have increased greatly. Nor could there have been a gradual environmental improvement, as no gradual decrease in heavy metal concentrations was observed in previous studies.

The last remaining conceivable cause is analytical errors in previous studies, particularly those performed before 1980. It is difficult to find any consistency in the previous results such as in the spatial distribution of heavy metals or in correlations with other properties like salinity.

Masan Bay

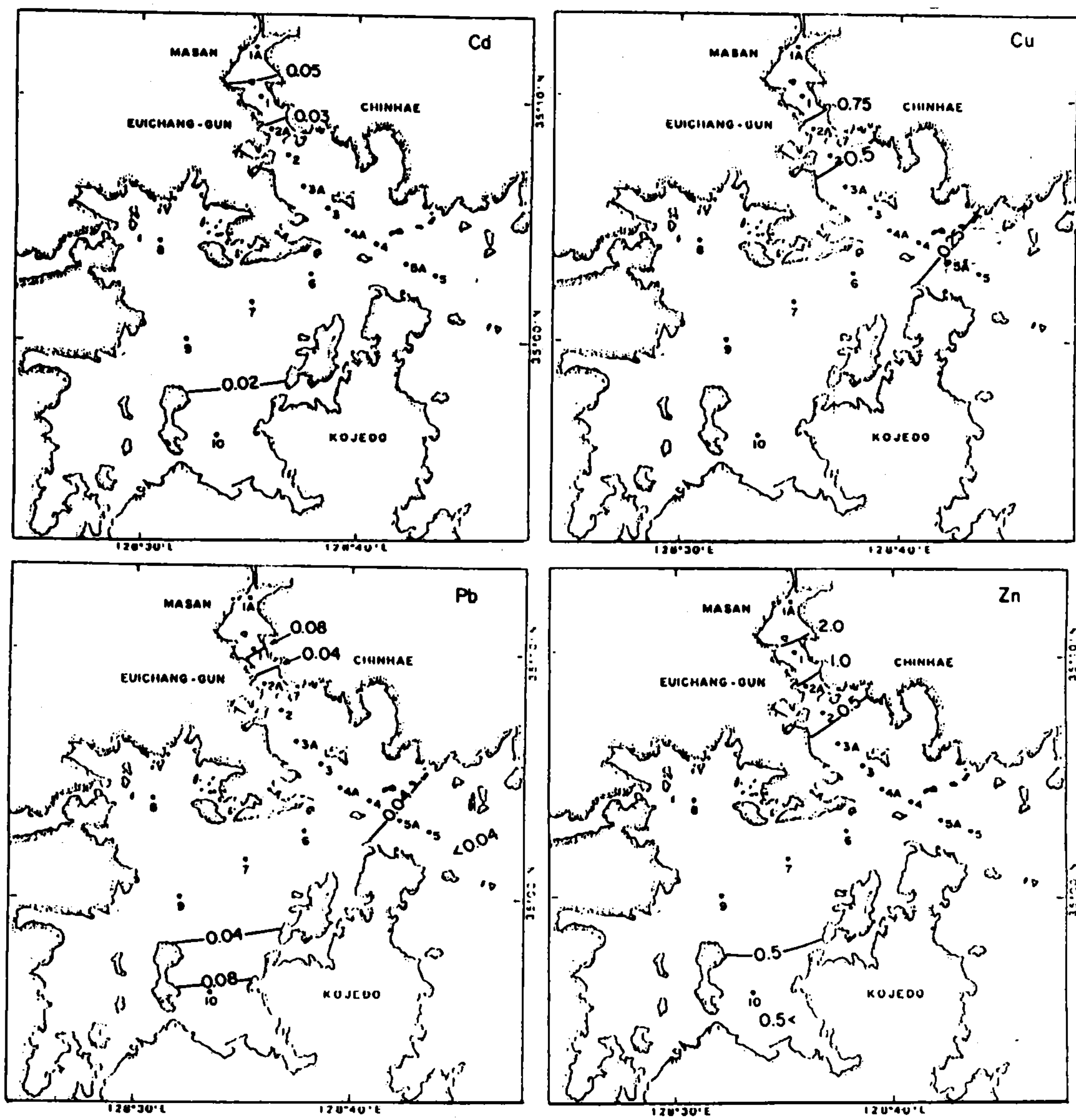
Masan Bay is on the southern coast of the Korean Peninsula about 100 km west of Pusan City. In contrast to Ulsan Bay, this bay is enclosed by many large and small islands which restrict the exchange of bay water with the open sea (Figure 11). There are large nutrient inputs from the city of Masan and Changwon Machinery Complex, so that Masan Bay is highly eutrophic and red tides are persistent in the summer. Oxygen concentration decreases substantially during the summer, to the point that part of the bay's bottom waters are completely depleted of oxygen in late summer.

Figure 11: Surface water sampling stations in Masan Bay



Heavy metal results for fifteen surface water samples collected in June 1986 (Figure 11) are shown in Figure 12. Despite the large potential heavy metal input and the stagnant nature of the bay waters, heavy metal concentrations do not appear to be very high except at a few stations in the inner bay. As in the case of Ulsan Bay, the present results showed metal concentrations several times lower than those of previous studies. This is in contrast to recent sediment analysis results which showed metal concentrations 5-10 times higher in the recently deposited sediment than the background levels (Lee et al., 1986). One conceivable explanation for this may be related to the extremely high biological activity in the study

Figure 12: Spatial distribution of dissolved cadmium, copper, lead and zinc in the Masan Bay surface waters



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MONITORING RED TIDES IN KOREAN WATERS

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ABSTRACT

As a consequence of more frequent outbreaks of red tides in the last decade, and particularly since huge red tides occurred in and around Jinhae Bay, in the southern coastal waters of Korea, from July to September 1981 and caused severe damage to oysters, mussels, ark shells and other fisheries resources, the National Fisheries Research and Development Agency (FRDA) has strengthened its red tide research and monitoring to predict red tide conditions and to consider countermeasures for reducing damage to cultured organisms.

Monitoring for red tide prediction in Korea is now undertaken weekly during June to September by FRDA research vessels in the serious red tide regions around Jinhae Bay. The results obtained are as follows: 25 species of phytoplankton were found to be the main causative organisms of red tides in Korean coastal waters. The most outstanding species before 1977 were the diatoms *Skeletonema costatum*, *Chaetoceros* spp., *Nitzschia* spp., and *Thalassiosira* spp. Since then, however, dinoflagellates such as *Prorocentrum micans*, *P. minimum*, *P. triestinum*, *Gymnodinium nagasakiense*, *G. splendens*, *Ceratium fusus*, *Heterosigma akashiwo* and *Protogonyaulax flatercula* have become the main causes of red tides.

Red tides have expanded to affect other areas such as Ulsan Bay, Inchon Bay and westward from Jinhae Bay. It is necessary to prevent eutrophication which causes red tides, and to develop counter-measures to reduce fisheries damage.

Introduction

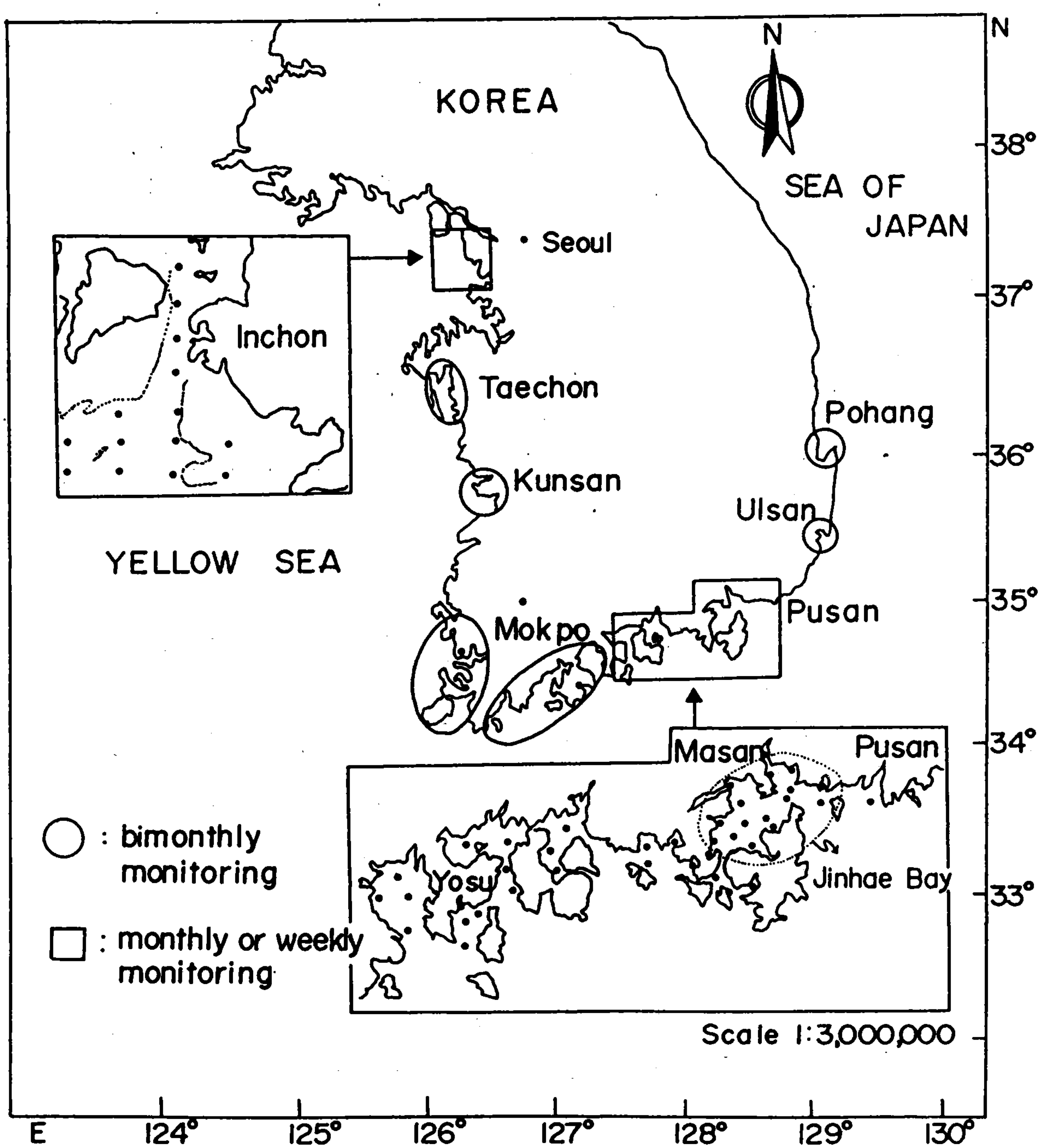
Outbreaks of red tides in Korean coastal waters have increased significantly in the last two decades, and they have recently caused severe damage to cultured shellfish and natural marine living resources. Out of 104 red tide occurrences along the southern coast of Korea between 1972 and 1979, more than half were in Jinhae Bay (Park, 1980). Since the unprecedented large scale red tides in and around Jinhae Bay in 1981 (Park, 1982), more frequent high density red tides have occurred every year, beginning in April in some areas of the bay such as Masan Bay and Haengam Bay, and lasting until October, while changing their causative species by month and year. The red tide phenomenon is now tending to spread widely over the whole area of the bay and to persist for a long time.

These red tide problems are having a serious economic impact on the aquaculture industry because they are concentrated in the southern coastal waters, especially Jinhae Bay and its vicinity, where intensive shellfish (oyster and mussel) growing areas and coastal fishing grounds are located.

Several workers have reported on the red tides in this area (Cho, 1978, 1981; Lee *et al.*, 1981; Park, 1982; Yoo, 1984). The red tides in coastal waters are now attributed to eutrophication caused by nitrogen, phosphorus and COD from domestic sewage and industrial wastes.

In order to predict the occurrence of red tides and to reduce their damage to fish and shellfish, the National Fisheries Research and Development Agency (FRDA) has carried out comprehensive red tide research and monitoring on a routine basis since 1972. About a hundred key stations have been established in the shellfish growing areas and around coastal industrial sites along the entire coast and especially in Jinhae Bay and its vicinity (Figure 1). In addition, in recent years monitoring has been strengthened in the serious red tide area of Jinhae Bay with weekly observations during the summer by FRDA research vessels and monthly helicopter observations. During the red tide monitoring period, each of the key stations is sampled for red tide organisms and for environmental parameters such as nutrients, dissolved oxygen, chemical oxygen demand, suspended solids, transparency, water temperature, and salinity. During heavy red tide outbreaks, temporary stations are established in the area in addition to the key stations to collect samples for more specific research.

Figure 1: Locations of red tide monitoring stations in Korea
(● = sampling stations)



Geographical occurrence of red tides in Korean coastal waters

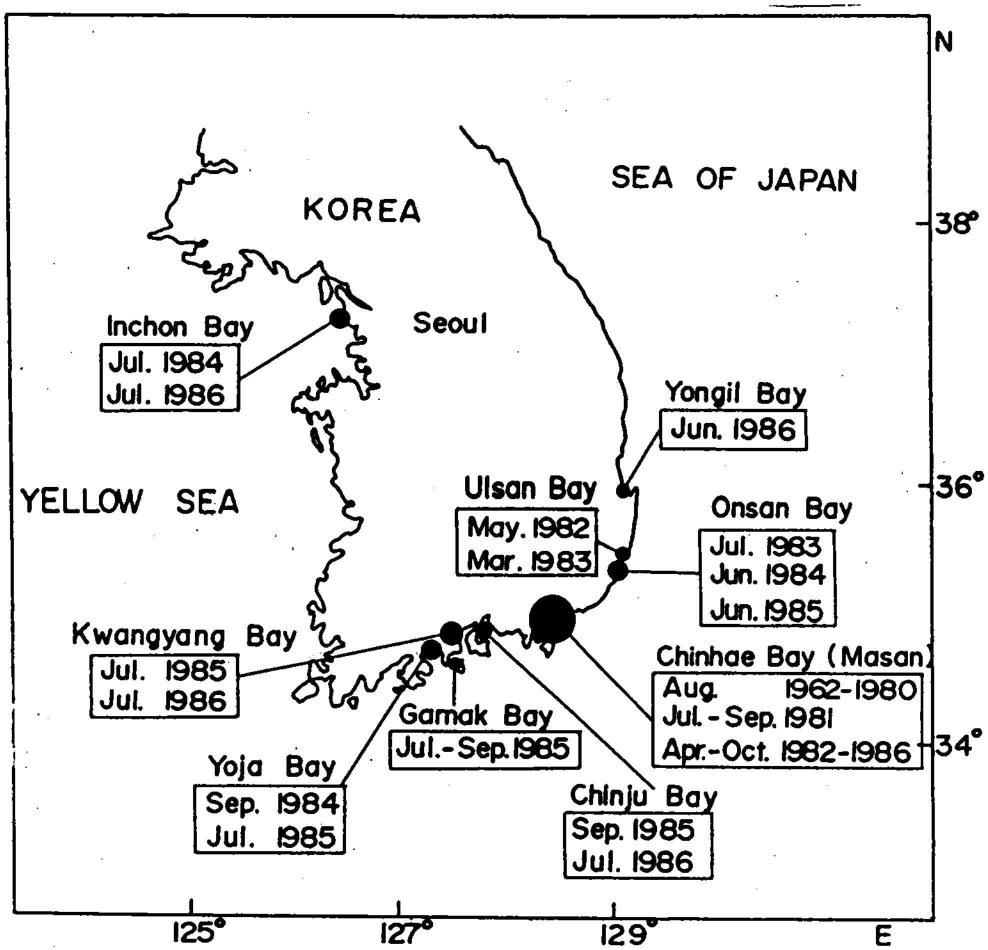
There was no scientific study of the geographic occurrence of red tides in other Korean coastal waters apart from Jinhae Bay before 1981. The occurrence of red tides in other regions such as Ulsan Bay, Inchon Bay and the area west of Jinhae Bay since 1982 is shown in Figure 2 and Table 1. The causative organisms and their cell density (cell numbers per millilitre) are significantly different from region to region. Masan Bay red tides showed highest density of *Prorocentrum* spp. and *Heterosigma akashiwo*, that of Ulsan Bay of *Prorocentrum micans* and *Peridinium trochoideum*, that of Yoja Bay of *Chaetoceros* spp., *Skeletonema costatum* and *Noctiluca scintillans*, and that of Inchon Bay of *Noctiluca scintillans*.

Table 1: Occurrence of red tides in Korean coastal waters

Area	Date	Red tide organisms	Percentage	Density (cells/ml)
Jinhae Bay* (Masan)	82.06	*Prorocentrum* spp.	83%	55,970
	84.06	*Heterosigma akashiwo*	99%	186,522
	86.06	*Prorocentrum* spp.	89%	42,500
Ulsan Bay	82.05.25	*Prorocentrum micans*	95%	10,260
	83.03.29	*Peridinium trochoideum*	95%	10,540
Onsan Bay	83.07.27	*Skeletonema costatum*	49%	4,700
		Thalassiosira sp.	46%	
	84.06.18	*Prorocentrum micans*	63%	4,000
		Skeletonema costatum	32%	
	84.08.29	*Skeletonema costatum*	95%	12,000
	85.06.09	*Heterosigma akashiwo*	95%	70,000
Inchon Bay	84.07.24	*Noctiluca scintillans*	98%	400
	86.07.06	*Noctiluca scintillans*	95%	380
Yoja Bay	84.09.20	*Chaetoceros* spp.	40%	8,200
		Skeletonema costatum	42%	
	85.07.25	*Noctiluca scintillans*	90%	300
Gamak Bay	85.07.25	*Noctiluca scintillans*	85%	240
	85.09.06	*Prorocentrum* spp.	90%	10,000
Kwangyang Bay	85.07.04	*Skeletonema costatum*	80%	2,400
	86.07.02	*Skeletonema costatum*	92%	72,100
Jinju Bay	85.09.10	*Cochlodinium* sp.	80%	2,000
	86.07.02	*Skeletonema costatum*	90%	15,300
Yongil Bay	86.06.24	*Prorocentrum* spp.	68%	8,200
		Heterosigma akashiwo	10%	
		Gymnodinium sp.	5%	

* In Jinhae Bay, red tides were first recorded in 1962; they have become more frequent and since 1982 habitually appear in April and last until October.

Figure 2: Geographical occurrence of red tides in Korean coastal waters, 1962-1986
(Dates of red tides in boxes)



Characteristics of the red tides of Jinhae Bay

The first scientific record of a red tide outbreak in Korean waters was in Jinhae Bay in 1962 (Park and Kim, 1967). Since then, the red tides have become more frequent in Jinhae Bay to the point where they have become a severe problem because of the damage to cultured organisms. It is significant that a majority of the red tides recorded in Korean waters have been in Jinhae Bay.

Among the eight different areas within Jinhae Bay, the highest density of red tides has been in Masan Bay as shown in Figure 3, and the lowest in the Gajodo area. With respect to red tide duration in Jinhae Bay, the red tides persisted in Masan Bay and Hengam Bay from April through September, and in other areas from July through September, based on phytoplankton abundance from 1981 to 1986. Masan Bay has become a chronic red tide area since 1982 (Figures 3, 4 and 6).

Succession of the organisms causing red tides

Twenty-five species have caused red tides in Korean coastal waters. There has been a succession in the main causative organisms over the years since 1962. The principal causes of red tides up to 1977 were mainly diatoms such as Skeletonema costatum, Chaetoceros spp., and Nitzschia spp. Since then, however, they have been replaced by dinoflagellates such as Prorocentrum micans, P. minimum, P. triestinium, P. dentatum, Gymnodinium nagasakiense, G. splendens, Heterosigma akashiwo, Protogonyaulax flatercula, and Eutreptiella sp., especially in the spring season (Table 2; Figures 5 and 6). Recent red tides have been characterized by large scale, long persistence and severe damage to cultured organisms, where previous ones were short small-scale outbreaks in some innermost bays.

Figure 3: Phytoplankton abundance indicating red tides in 8 areas of Jinhae Bay from April to September, 1981-1986

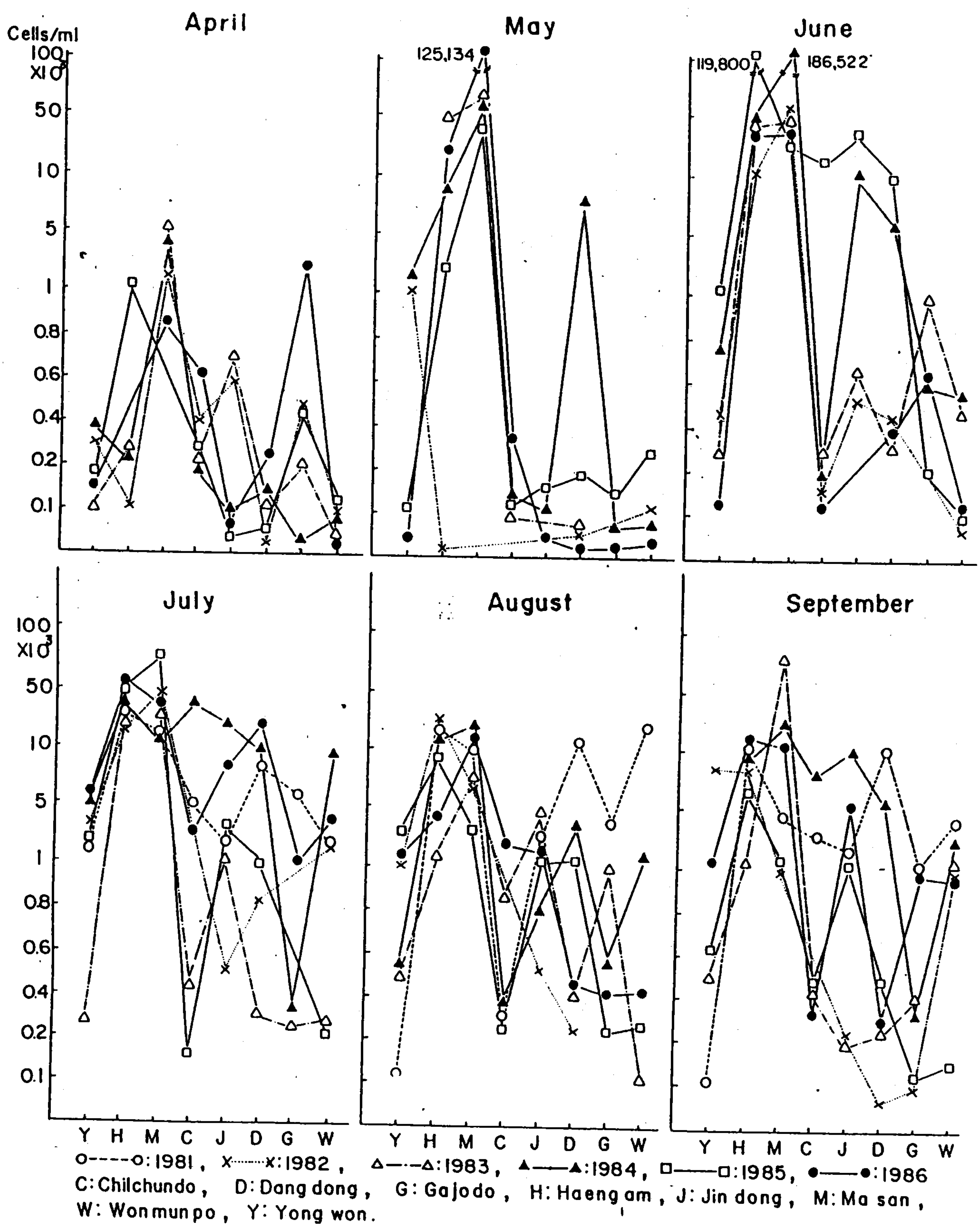


Figure 4: Distribution of red tides in Jinhae Bay, 1981-1986

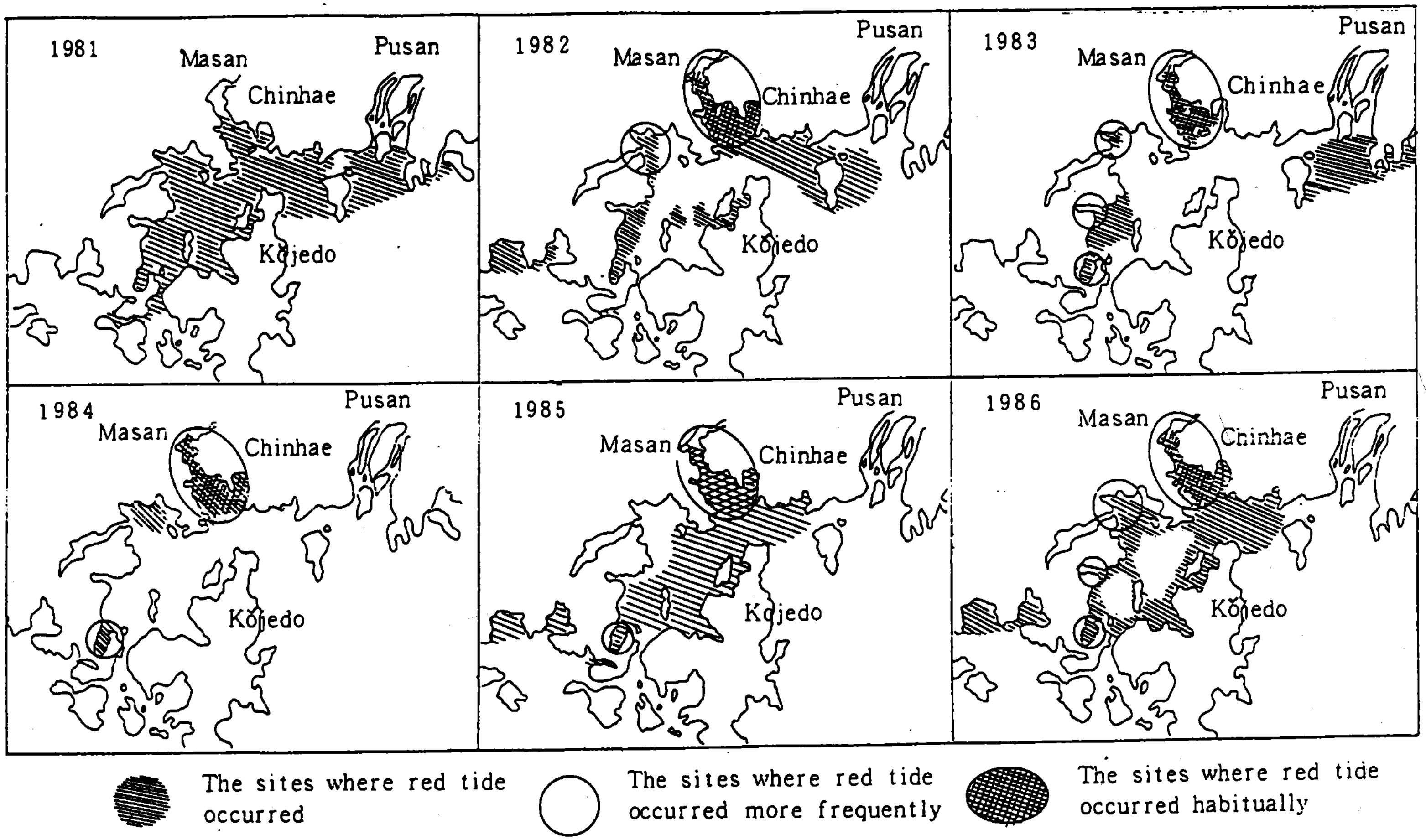


Figure 5: Yearly and monthly changes in red tide organisms in Masan Bay, 1981-1986

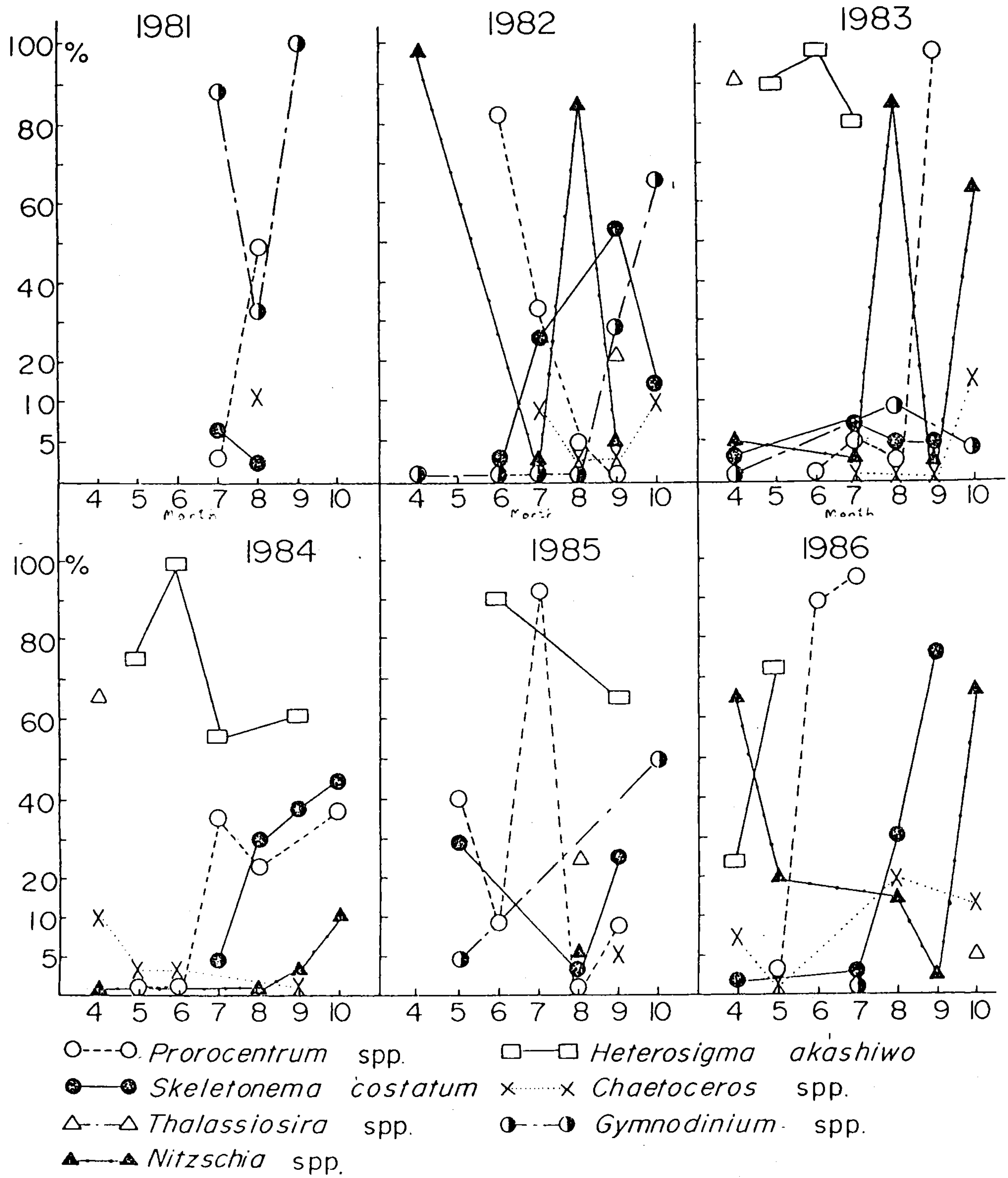
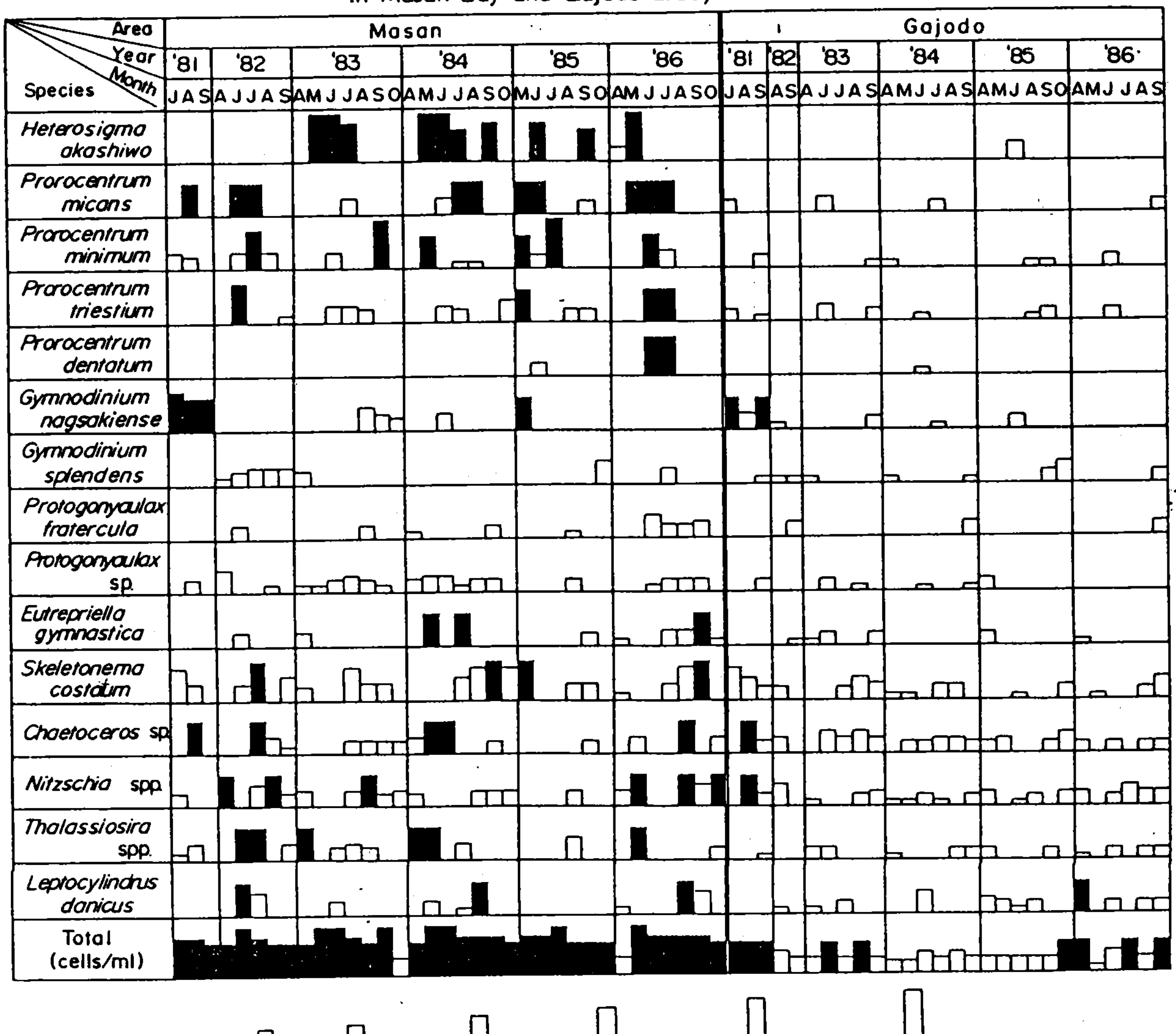


Figure 6: Comparison of causative organisms and periods of red tides in Masan Bay and Gajodo area, 1981-1986



0-10 10-100 100-500 500-1,000 1,000-10,000 10,000-50,000 50,000< cells/ml. Black bars indicate red tides (over 1,000 cells/ml), but only *Skeletonema* means density over 10,000 cells/ml.

Table 2: Yearly changes in composition (%) of red tide organisms in Masan Bay

Species \ Year	'61	'72	'74		'77	'78	'79	'80		'81			'82					'83						'84						'85					'86					
Month	Oc	Ju	Jul	Au	Au	Au	Jul	Jul	Se	Jul	Au	Se	Ap	Ju	Jul	Au	Se	Ap	Mo	Ju	Jul	Au	Se	Ap	Mo	Ju	Jul	Au	Se	Mo	Ju	Jul	Au	Se	Ap	Mo	Ju	Jul	Au	Se
Total (cells/ml)										18	11	5	2	56	43	7	1	5	65	54	25	8	77	3	125	187	15	25	31	40	39	76	4	2	03	70	43	42	12	18
Chaetoceros spp.	51	16	60	23	37	7	5				17				8									11															20	
Leptocylindrus danicus				27				8						9														38											10	
Nitzschia spp.	43			15		6			5				99			85		4				86											5		65	20			15	
Skeletonema costatum		80	14	16	37		10		89	6					27		52				6							30	38	29				26					30	76
Thalassiosira spp.																	20	92						66									25							
Gymnodinium sp.										89	39	99										9								5										
Gymnodinium splendens																	27																							
Prorocentrum spp.						71	81	72			42			83	34								99				36	24		41	9	92		8			89	95		
Protogoniaulax fratercula																																					2			
Heterosigma akashiwo																			91	98	81				75	99	56		61		90			65	25	72				

※: Unit of total cells/ml : 1,000

According to Adachi et al. (1979, 1982), the main red tide causing organisms in Ise Bay, Japan, for the five years from 1972 to 1976 were Noctiluca miliaris in 1972 and 1974, Skeletonema costatum in 1973 and 1975, and changed to dinoflagellates such as Peridinium trochoideum, Noctiluca scintillans, Prorocentrum minimum v.m.l. and Olisthodiscus sp. in 1976. In the same bay in 1977-1980, Prorocentrum spp. caused red tides in 1977-1978, but was replaced again by the diatoms Skeletonema costatum, Chaetoceros spp., Nitzschia spp., and Thalassiosira spp. in 1979-1980. The red tide organisms reported by Honjo (1974) in Hakada Bay, Japan, were Skeletonema and Noctiluca in 1971, Prorocentrum spp. and Olisthodiscus sp. in 1972, and Gymnodinium type '65 from 1973. The red tide species with the highest frequency in the Seto Inland Sea during 1973-1979 were Noctiluca scintillans, Skeletonema costatum, Olisthodiscus sp., Gymnodinium sp., Prorocentrum sp. and Ceratium spp. in that order; red tides of Chattonella were of relatively low frequency but caused much damage to cultured fishes (Uno, 1980). In France, red tides have been caused by Dinophysis accumilata, Prorocentrum redfieldi, P. micans, Polychricus sp., Pseudopedinella sp., Pyramimonas disomata, Gonyaulax spinifera, Scrippsiella sp., Heterocapsa triquetra, Ceratium tripos, Gymnodinium sp., and Peridinium sp. In Spain, Gymnodinium catenalum was responsible for paralytic shellfish poisoning (PSP) in 1976, when there were outbreaks of PSP in various countries of Europe caused by mussels cultivated in the Galicia Estuary (NW Spain). Other organisms known to cause red tides are Amphidium sp., Chaetoceros didymum, Mesodinium rubrum, Eutreptiella sp., Noctiluca scintillans, Olisthodiscus luteus, Ceratium furca, Prorocentrum triestinum, and P. rostratum.

In Korea, Prorocentrum species have become the habitual causative species for red tides in Masan Bay and Haengam Bay since 1978. Gymnodinium nagasakiense was the outstanding single phase species for the huge unprecedented red tides of 1981. Heterosigma akashiwo has recently become the main spring red tide organism in Masan Bay and its vicinity as a consequence of the inputs of organic pollution. However since 1978, Prorocentrum spp. and Heterosigma akashiwo lose their dominance after August or September, to be replaced by Skeletonema costatum and Nitzschia spp. Skeletonema costatum has become a main red tide species in competition with Prorocentrum and Heterosigma all year round except in the spring. Recently there have been increasing concentrations of Protogonyaulax tamarensis and Chattonella sp. in April and May, with Chattonella occurring in large numbers in Jinhae Bay in April 1983.

Periods of occurrence of red tides

In order to study the outbreaks and duration of red tides throughout the year, a comparison of seasonal changes in phytoplankton abundance has been made in Masan Bay for the years 1981-1986 (Figure 5).

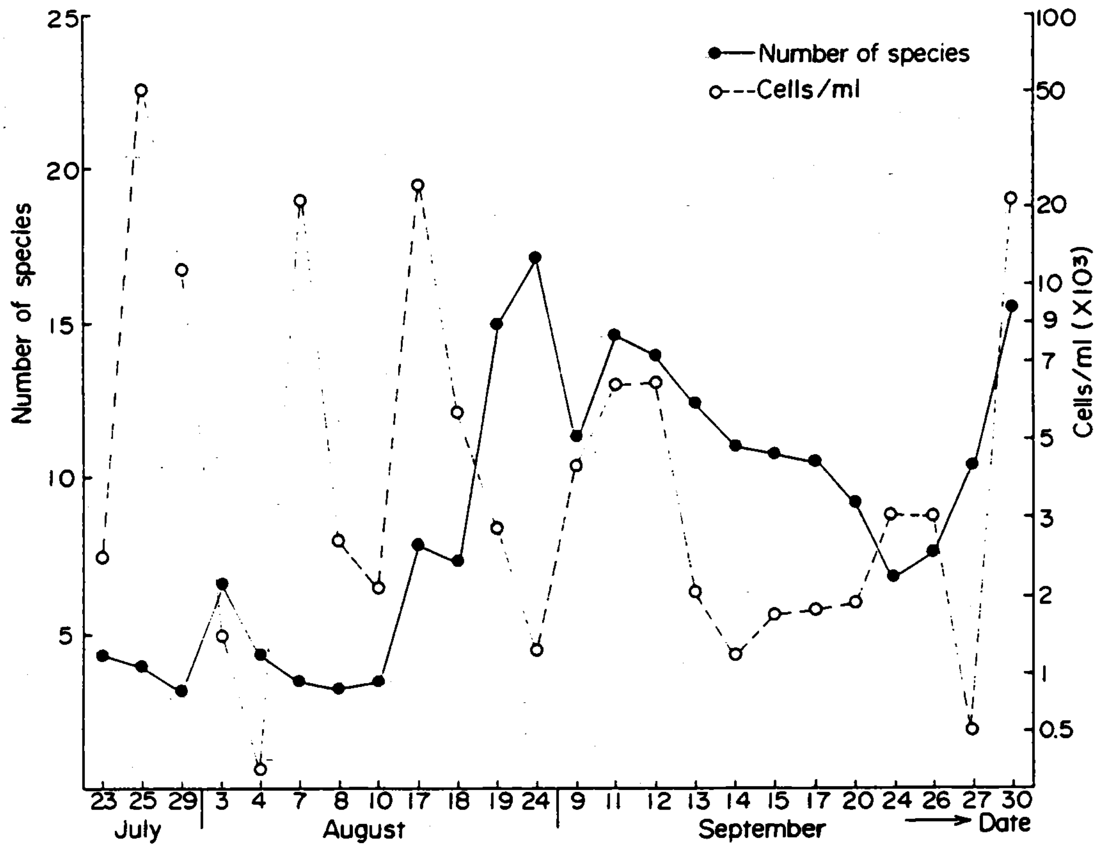
The unprecedented red tides of 1981 lasted from July through September and were widespread, affecting areas such as Pusan and Chungmu. In 1982, the red tides caused by Prorocentrum, Skeletonema and Nitzschia appeared in April and lasted through September, with a maximum density in September; Gymnodinium splendens formed 86% of a bloom in October. The 1983 red tides also continued from April until September, but Heterosigma replaced Prorocentrum as the main spring causative species. Red tides have continued to progress each year through 1986. In summary, the red tide phenomena in Masan Bay begin in April and last through October, although the period, density and size of the red tides depend on weather conditions. Heavy eutrophication, with high nitrogen and phosphorus concentrations, is known to produce these red tide outbreaks.

Relationship between species number and density in red tides

During the period of red tides in and around Jinhae Bay from July to September 1981, there were from 3 to 20 species present, with two distinct phases (Figure 7). Small scale changes in species number with less than 5 species occurred through August 10 during the heavy simple phase type red tides caused by Gymnodinium type '65. From late August there were large scale species changes involving 10 to 20 species, dominated by Skeletonema, Nitzschia and Chaetoceros; red tides during this period had complex phases or disappeared temporarily.

The density of red tides was inversely related to species number during the heavy red tides of 1981. The highest densities generally appeared with the smaller numbers of species, while lower densities were associated with larger numbers of species.

Figure 7: Relationship between number of species and density of red tide organisms Jinhae Bay, 1981



Conclusions

As a consequence of the more frequent outbreaks of red tides in the last decade and their extension from Jinhae Bay to other regions since 1982, red tides have become a severe problem in Korea causing major damage to fisheries.

The recent red tides can be characterized as large scale, with high concentrations of a variety of organisms, of long duration, and with diatoms being succeeded by dinoflagellates supposed to be harmful to living organisms. Therefore red tide research and monitoring in Jinhae Bay should be strengthened to implement the following immediate and long-term programme:

a) intensive monitoring for red tides in the high density shellfish growing areas of greatest economic importance;

b) research on mechanisms for outbreaks of red tides and on fish kills caused by red tides;

c) investigation of the origins of factors promoting the growth of red tide organisms and their chemical and biological assay;

d) taxonomy of toxic plankton involved in red tides, including their cysts;

e) toxicological studies of red tide organisms and assays of shellfish for PSP;

f) studies of the process of eutrophication and its elimination;

g) determination of the physiological requirements of red tide organisms; and

h) analysis of the physical processes which affect the formation of red tide patches

An information exchange system for red tide prediction is extremely important and should be promoted urgently. There should be a rapid reporting system whereby anybody who first finds a red tide outbreak, whether people culturing organisms, members of fisheries co-operative unions, extension service workers stationed in important fisheries villages, or fishermen, should report the exact circumstances to the Fisheries Research and Development Agency (FRDA), either directly or through the fisheries administration section of the prefecture. The FRDA can then investigate the details required for a comprehensive analysis and collect field scientific survey data. Such a reporting system will be necessary for any prediction programme.

The system should aim to predict the main causative organism concentrations, the size and expected duration of the red tides, the occurrence of harmful species, the estimated effects of the red tides on the biota, and the necessary countermeasures to be taken.

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THE NEED FOR AND POTENTIALS OF INTER-REGIONAL CO-OPERATION

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ABSTRACT

Each Regional Seas Action Plan has been developed in response to the specific needs of its region for environmental protection. However all the Action Plans share many features and respond to common problems that would benefit from inter-regional co-operation.

Regions with similar coastal ecosystems such as coral reefs and mangroves should exchange information on those ecosystems and their management. Techniques for surveys, monitoring and analysis should be harmonized and intercalibrated so that the results can be compared. Participants from several regions can be grouped for specialized training to make courses more cost-effective. Experiences of one region in regional co-ordination, data analysis, legislation and other fields can often be useful to other regions.

Inter-regional co-operation should be developed at the levels of regional co-ordinators, governments, research institutions and individual specialists.

The needs for regional co-operation

The oceans form a global interconnected system. No one nation can think of managing its part of the ocean in isolation from all the rest. Yet organizing a world co-operative programme of ocean management presents enormous practical difficulties. Nations that share a common coastline, or that surround or are scattered across a common sea can more easily see the importance of regional co-operation to solve the environmental problems of their shared ocean resources. This was the origin of the Regional Seas Programme of the United Nations Environment Programme.

In each region the governments have identified their own priority problems: oil pollution, nature conservation, terrestrial inputs, resource management, waste dumping, etc. The regions differ in their geography, cultures, governmental procedures, scientific infrastructure, economic and political systems, and existing regional organizations. These differences are expressed in their action plans and programme structures.

However, there are also many shared features and common problems, as are evident in the papers presented in this symposium. The three regional seas programmes and all the Pacific countries represented here share the same ocean, and have much to learn from each other both in their approaches to problems and their solution, and in the specific information concerning their common resource. Discussions on inter-regional co-operation first began in the Pacific as part of the UNEP session at the last Pacific Science Congress in 1983 (Dahl, 1985), when some of the action plans were still in the very early stages of implementation. As the programmes have developed over the last 4 years, there has been a small beginning to inter-regional activities in the Pacific, including some joint training courses for the East Asian Seas and the South Pacific, and even some participants from other regions. This is an appropriate time to see how this co-operation can be expanded.

Potential areas of inter-regional co-operation

There are a number of ways that different regional programmes for the environmental protection of marine and coastal areas can benefit from inter-regional co-operation. Where regions have **common ecosystems, features, species or resources**, they can share information on the status of such resources as well as experience in dealing with management problems. For instance, coral reefs and mangroves are common in the East Asian Seas and the South Pacific, as well as the northern parts of the South-East Pacific. Certain ocean currents and water masses traverse the whole Pacific from one region to another. Some widespread marine species occur throughout the regions, or like turtles and skipjack tuna may migrate from one region to another. Species that are sensitive and difficult to manage like the dugong also may be distributed widely. The special problems of island environmental management are shared by island areas across all the regions.

The most appropriate **techniques for surveys, monitoring and analysis** should also be shared and harmonized so that the results can be compared between regions. Field techniques for data collection are steadily being improved with the use of remote sensing and better monitoring methods; such new techniques should be shared widely. Analytical techniques for marine pollutants require standardization and intercalibration so that data can be pooled on a world basis. The UNEP Reference Methods for Marine Pollution Monitoring illustrate the common approaches that should be applied throughout the different regions. Many groups of marine organisms are still not well understood scientifically; inter-regional co-operation in working out the taxonomy of important groups can help in the intercomparison and exchange of results. The masses of data produced by national and regional programmes need to be stored and processed so that they can be drawn upon and used; the use of common data processing formats and storage systems can make for efficient data exchange in the best interests of all concerned.

The **training of researchers and technicians** is a slow and expensive process. Grouping training needs into inter-regional courses can be more cost effective. The creation of Pacific centers of excellence in certain fields may be the only way to make high quality scientific facilities available to regions that lack scientific infrastructure. Producing training materials and audio-visual supports dealing with Pacific problems and solutions can make training across the three regions concerned more effective.

In a number of fields where the regions share **common problems**, co-ordinated action may be needed to respond to them. Certain pollutants or potential pollutants may have an ocean-wide dimension, such as persistent toxic chemicals like PCBs and organochlorine pesticides, plastics, oil, and radioactive products dumped or released into the ocean. All the regions are facing common difficulties with coastal zone planning, environmental impact assessment, resource management, nature conservation and other problems where the interchange of experience would be useful. Urban pollution is common to all Pacific urban areas, and there is a widespread need for research on appropriate technologies for pollution control and waste treatment that would be applicable across the regions. The regions may also find it useful to pool their research efforts in certain fields where country and regional resources alone are inadequate.

Where certain environmental dangers threaten the whole Pacific, it may be in the interest of the many small countries in all the regional action plans to make common cause in their pressures, protests or initiatives at the international level.

Inter-regional co-operation can also be beneficial in sharing approaches to **legislation, administration and implementation**, in the **review, publication and exchange of scientific results**, and in the early **exchange of information** on research in progress.

Fostering inter-regional co-operation

It is important to remember that inter-regional co-operation can take place at many levels, depending on the type of problem or topic. The first efforts usually begin at the level of international agencies or of the regional co-ordinators for each action plan. However co-operation at the level of individual governments, research laboratories, associations of researchers or research institutions, or even individual specialists should also be encouraged when appropriate.

The first step in fostering inter-regional co-operation is to define the areas of common interest, or in which knowing more about other regions would make a region's activities more effective. It is then necessary to define the kinds of co-operation that would be most effective: meetings, newsletters, combined training, the twinning of research institutions, exchanges of personnel, technical co-operation using experts from other regions, exchanges of educational materials, etc. It can also help to analyse those problems or barriers that make inter-regional co-operation difficult and to identify the best ways to overcome them.

As co-operation between the different regional programmes is strengthened, they will become the foundation for the global approach to the protection and management of the oceans envisaged by the governments of the world at the 1972 United Nations Conference on the Human Environment.

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DISCUSSION ON INTER-REGIONAL CO-OPERATION

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ABSTRACT

The action plans have provided a strong base of sub-regional co-operation upon which existing inter-regional co-operation has been built in such areas as reports on the state of the marine environment and the effects of climate change, scientific organizations, methodology and intercalibration, and participation in international scientific activities. Other UNEP-supported inter-regional activities are planned between secretariats and in the creation of regional analytical centres.

The regions highlighted needs for better information exchange; research co-operation on El Nino, coral reefs, red tides, etc.; joint preparation of environmental impact assessment guidelines, bioassay techniques, and audio-visual training materials; development of regionally appropriate environmental control technologies and waste disposal options; inter-regional training activities, internship programmes and expert reviews; combined approaches to problems such radioactive pollution, seabed mining, protection of the high seas, and marine park management; and continued inter-regional scientific meetings.

In the light of the presentations of the scientific accomplishments of each of the regional action plans, the participants were invited to discuss ways in which co-operation could be further developed between the regions in the interests of the protection and management of the whole Pacific Ocean, and eventually of all the seas of the world.

The discussion was opened by Stjepan Keckes, who reviewed the progress on inter-regional co-operation to date. Each action plan provided the basis for good sub-regional co-operation under the control of the governments concerned. UNEP will continue to support such co-operation both at the government level and among scientists. The regional reports on the state of the marine environment (including 4 in the Pacific), now being prepared, will contribute the the global report to be issued in 1989. Reports are also being prepared on the potential ecological and socio-economic effects of long-term climate change, which risks being a bigger environmental disaster than any other today. Advisory nongovernmental organizations of scientists or scientific institutions have been created in the East Asian Seas and the South Pacific. The intercomparability of data is essential, requiring continuing efforts to harmonize methodological approaches through such activities as joint meetings on methodology and intercalibration. Scientists in developing countries lack proper exposure to international science; these links are being forged through participation of scientists from the regions in GESAMP, and in the Pacific Science Congress and other international meetings.

All these activities will need to be continued in the future. There will also need to be meetings of secretariats and regional co-ordinators to try to improve the flow of information. For world-wide joint programmes like the mussel watch of GESAMP, it will be necessary to establish some regional analytical centres in each ocean to monitor and co-ordinate measurements of chlorinated hydrocarbons on a global scale. Discussions are now underway to explore the adoption of an action plan for the North-West Pacific which up to now has not been part of the UNEP-sponsored Regional Seas Programme. A large-scale conference on interdependence of environment and development may be organized for the Pacific region with UNEP support in 1990 or 1991. The Pacific is not presently threatened by radioactivity, but the Chernobyl accident has shown the danger of neglecting the capacity to monitor radioactive pollution; an independent regional centre for such monitoring may be needed to serve the island states.

The regional co-ordinators then reviewed the ideas and priorities for inter-regional co-operation as seen from their regional perspective. For the South-East Pacific, the following subjects were suggested:

--- joint research and exchange of information on the physical oceanographic and meteorological phenomena associated with the El Nino-Southern Oscillation;
--- co-ordination at both a technical and political level of actions concerning marine radioactive pollution;
--- adoption of regionally-appropriate guidelines for environmental impact assessments, including socio-economic aspects, suitable for developing countries;
--- preparation of protocols for bioassay testing techniques using Pacific organisms;
--- production of audio-visual training materials on Reference Methods for Marine Pollution Studies;
--- studies of seabed mining and its environmental implications;
--- development of appropriate environmental control technologies suitable for environmental management in the Pacific;
--- exchange of experience and assistance in marine park management;
--- better exchange of information, such as that appropriate for regional newsletters;
--- determination of the appropriate forum for discussions of subjects of common interest, and for making joint declarations.

The co-ordinator for the South Pacific Regional Environment Programme endorsed the suggestions for inter-regional co-operation given in the paper opening the session by A. L. Dahl. There is a particular need for a greater transfer of information and knowledge such as at the present meeting, but perhaps every 2 years, so that environmental scientists can catch up with progress elsewhere, and can look for ways to help those that are lagging behind. Directories and other ways of encouraging a wider association of scientists are also useful. It is also necessary to investigate means of protecting the high seas in the Pacific, since the present regional agreements cover only the 200 mile exclusive economic zones. The pockets of high seas within and between East Asia, the South Pacific and the South-East Pacific are of particular concern.

For the East Asian Seas, most needs had already been suggested in the preceding discussion. In the area of information exchange, it is very important to improve communications among scientists and institutions, such as through joint training courses and workshops which could involve all three regions. On-the-job training through an internship programme would allow trainees to spend a few months working with laboratories and researchers in another region; the regional secretariats could exchange information on such opportunities. Where the regions share common ecosystems such as coral reefs, networks should be formed involving researchers in all the regions concerned; the coral taxonomy training course was a good recent example of such co-operation. Red tides are an increasing problem in the East Asian Seas that would benefit from co-operation with other regions with similar problems. It was pointed out that East Africa and the Caribbean also suffer from red tides, but that research on such approaches as a rapid test for contaminated fish had not yet produced satisfactory results.

In the general discussion that followed, a number of additional points were raised. There is a need to integrate the work of visiting scientists more carefully into national research priorities, both to increase interaction with local scientists and to control the few scientists that do not always respect national regulations. It is important for scientists to be committed to transferring knowledge to other countries where they are working.

It was pointed out that the regional programmes were not well known among outside scientists, even where they had been in existence for ten years, and that more could be done to promote them within the scientific community.

More could also be done in all the regions to develop methods to justify the protection of ecosystems, such as by converting ecological value to economic value. Many countries also faced similar problems in the ultimate disposal of wastes collected in pollution control or reception facilities. Many laboratories would benefit from the visit of an expert who could recommend improvements. Inter-regional discussion on how to fix suitable environmental quality standards appropriate to local conditions would also be useful.

Apart from the specific points mentioned above, the theme most frequently raised in the discussion was the need for wider exchanges of appropriate kinds of information between programmes and scientists. UNEP is making some plans to encourage this, but much depends on the efforts and initiatives of the regional programmes and the individual scientists themselves.

It was clear from the reactions of those present that the regional programmes already underway and the continuing UNEP efforts to stimulate inter-regional co-operation are gradually building into a larger co-ordinated effort to protect the marine and coastal areas of the Pacific, and indeed of the whole world.

REGIONAL CO-OPERATION ON ENVIRONMENTAL PROTECTION OF THE MARINE AND COASTAL AREAS OF THE PACIFIC

(Hanyang University, Seoul, Korea, 25-26 August 1987)

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