Population-environment relations in tropical islands: the case of eastern Fiji

Based on the findings of the Unesco/UNFPA pilot project ‘Studies on population-environment relationships in the eastern islands of Fiji’

Edited by H.C. Brookfield
Preface

Unesco's Man and the Biosphere (MAB) Programme and in particular its project area on island ecosystems (MAB Project area 7) offers an appropriate framework for the study, under relatively controlled conditions, of the entire spectrum of ecological, economic, social and demographic factors that influence men's relationships with the biosphere. At the same time, it provides for island people and their governments the opportunity to focus international scientific interest on the problems of their specific environment, which are based upon limited and often non-renewable resources. Within the United Nations system, the United Nations Fund for Population Activities (UNFPA) has a specific interest in, and a mandate to support activities aimed at both increasing knowledge on population, resources, and environment interrelationships, and developing methodologies for integrated approaches to research, planning and action in these fields.

Consequently, Unesco-MAB and UNFPA joined efforts to focus one of the early-starting MAB field projects on island systems on population-environment interactions. This project - which was undertaken on the eastern islands of Fiji - forms the basis of the present MAB Technical Note. The project was formally approved in 1973, following consultations between the Government of Fiji, Unesco and UNFPA. The technical and operational responsibilities for the execution of the project were entrusted to Unesco-MAB.

The project represented a first-stage pilot study on population/environment relationships. Unesco and UNFPA considered that it would be useful for the initial research effort to select a group of islands having characteristics representative of a wide range of tropical islands - a group which would be a suitable site for a research project in its own right, as well as serving as a pilot area in which methods could be developed and problems identified for follow-up work in other parts of the tropical world. It was with these considerations in mind that the eastern islands of Fiji were selected as the site for the first-stage pilot study.

In keeping with the overall aims of the MAB Programme, the central objective of the Fiji project, and the one to which the Government of Fiji attached the greatest importance, was to provide a set of research guidelines for decision-making on population/environment problems in the context of provincial and local development in the small islands of Fiji, most of which lie in the area chosen for study east and south of Viti Levu and Vuvu Levu, the two major islands of the country.

Field work started in Fiji in 1974, and ended in late 1976. The field work was followed by a lengthy phase of synthesis and writing-up. Initially, this entailed preparation of an overall synthesis containing 'Guidelines for decision-making' in Fiji and a series of island reports dealing with specific islands or topics. A list of publications from the project is given as Appendix 1.

The present Technical Note represents the final step in the phase of synthesis and publication. It attempts to provide an overview and extrapolation of the research results from the Fiji project. As such, the Technical Note responds to one of the major objectives of the project, which was to provide reference information and to develop methodologies which would be useful also outside Fiji, primarily in island situations but also in rural areas in developing countries worldwide.

The content of this Technical Note ranges over a broad range of issues. It includes a report on the difficulties involved in creating an interdisciplinary research team. It proposes different methodologies to estimate carrying capacities of human population. It examines problems of management of natural resources, as well as of man's impact on island environments.
Finally, it develops some guidelines on how to integrate population programmes and environmental management in small island regions. Unesco hopes that the Technical Note will act as a stimulus for similar studies on population, resource, environment relationships on a country-by-country basis. The MAB Programme would provide an ideal structure to launch these exercises and to benefit from the pilot studies undertaken jointly by Unesco and UNFPA.

Collaboration between Unesco and UNFPA in this field is continuing. A second-stage project on population development, environment studies started in October 1979 on some islands in the eastern Caribbean, primarily Barbados. The new project is receiving an important input from the Institute of Social and Economic Research (ISER) of the University of the West Indies. It is hoped that the present Technical Note will facilitate the transfer of the Fiji know-how and experience into this new research undertaking, which deals with much more complex and hence even more representative population/environment interactions.

Unesco and UNFPA take this opportunity to express their gratitude to the Government of Fiji for the ready welcome it extended to the project in the eastern islands and for its collaboration in the project work. Particular mention should be made of the collaboration of the District Administration, the Extension Staff of the Ministry of Agriculture, Fisheries and Forestry, the staff of the Ministry of Health and other departments, together with the people of the islands, chiefs and commoners, Fijians and non-Fijians alike, without whom the field research of the project could not have been successful.

Further, Unesco wishes to thank all the United Nations organizations, at Headquarters and in the field, that showed their continued interest and in many cases contributed invaluable help to the project. UNFPA financed all the field expenses, and the successive UNFPA coordinators for the South Pacific region, Raja Rao and Sharon Epstein, assisted the project in many ways.

The project is indebted to many international and national organizations and institutions for their cooperation, for example in granting leave of absence to their collaborators. It is difficult to single out some without being un-

just to others whose help was also extremely valuable. The Office de la Recherche Scientifique et Technique Outre-Mer of France, and especially its New Caledonia branch, made the services of some of their research workers available without charge, as did the South Pacific Commission in one particular case. The Australian National University and the University of Melbourne very generously hosted the project during its reporting period. The Unesco National Commission of Australia and the Australian MAB National Committee provided substantial financial aid towards the cost of mailing project reports to Fiji and Paris.

The list of scientists involved in the field work of the project is given in Appendix 1. Unesco is grateful to all of them for their excellent collaboration. Particular thanks are due in this respect to the project's Chief Technical Adviser and editor of this Technical Note, Dr. Harold Brookfield, Professor of Geography at the University of Melbourne. The project owes a large part of its success to his unfailing devotion, from the planning stage through the field research period to the reporting phase. In addition to his specific role in the Fiji project, Dr. Brookfield has collaborated in MAB since its early stages, playing an important part in the development of the 'island project area' in particular, and in reinforcing the contribution of the social sciences to the MAB Programme in general.

Unesco gratefully acknowledges the work of Mrs. M. Brookfield, a geographer herself, who contributed significantly to the field research and the writing-up of final reports. Finally, Unesco would like to thank the numerous other persons who were associated with the project, not least the various project secretaries whose names are listed in Appendix 2.

Appendix also mentions a number of specialists who never became formal members of the project, but who influenced it through comments or discussions at one time or another.

The views expressed in this Technical Note are those of the authors, and are not necessarily shared by Unesco or by UNFPA. The designations employed in this Technical Note do not imply the expression of any opinion whatsoever on the part of Unesco and UNFPA concerning the legal or constitutional status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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The need for population/environment studies

The tendency to deal with population increase as a self-contained problem now seems outdated. During the last decade, it was widely recognized that a country's 'population problem' was not only a question of high fertility, but also one of nutrition, security in old age, the status of women, economic conditions, and so on. Moreover, population growth is no longer seen as the only concern. Often more critical are problems linked with massive migration flows, such as the concentration of the world's population in urban areas not prepared for this influx.

It is also now generally recognized that there are complex systems relations among population dynamics, the availability and use of natural resources (mainly connected with the state of agriculture), problems of the environment, and economic development in general in any given geographical unit, both on a national and a global level. Knowledge of these interrelationships is still woefully insufficient. Only highly aggregated and simplified global and regional models have been put forward relating population to resource availability, environmental carrying capacity and development.

The limitations of global synthesis are obvious. The population/environment situation differs from country to country and varies even from area to area within most countries, in particular the larger ones. The problems of assessing population/resource ratios, and of defining measures for their beneficial adjustment, must be tackled on a disaggregated national and area basis. In fact, there seems to be a need for almost every country to develop a population/resource/environment model for its particular national situation and for its major geographical subdivisions.

What seems certain is that these exercises of analysis and inventory-taking at the national level will underline global resource interdependencies which have developed over the last century and which have intensified over the last decades. The population carrying capacity of an area is no longer directly related to its capacity for food production. The situation has evolved in a direction which often makes a country's capacity and 'elasticity' to integrate in global and continental economic exchanges the decisive variable of its population carrying capacity at aspiring levels of welfare. Much still needs to be done to ensure that the benefits of this global interdependency are more equally distributed, and that small systems which integrate into larger ones do not lose their capacity for self-reliance and endogenous development.

The wide recognition of the importance of endogenous development makes it more important than ever to bring about more rational management of indigenous natural resources in developing countries. It seems paradoxical that in many developing countries these resources are not used optimally, although imports of food have to be increased year by year owing to population growth and urbanization.

Not only is knowledge of population, resources, environment and development interactions still grossly insufficient, but there is a lack of methodological tools to describe and measure such interactions and to influence them through integrated policy-making and programming. National population policies and programmes operate with notions such as overpopulation and underpopulation. What is the yardstick for considering a particular country or area as overpopulated and another as underpopulated? How do we estimate population carrying capacities in a primarily rural economy or even in a multi-sectoral economy? There are many methodological questions, and not enough
The UN World Population Conference of 1974 was aware of this situation and included as one of the objectives of the World Population Plan of Action: 'To advance national and international understanding of the complex relations among the problems of population, resources, environment and development, and to promote a unified analytical approach to the study of these interrelationships and to relevant policies' (paragraph 150).

Among the recommendations of the Conference, paragraph 78 stresses the high priority given to research activities on population problems in this Plan of Action. Point (n) of paragraph 78 is concerned with the following research areas:

- The interrelationships of population trends and conditions and other social and economic variables, in particular the availability of food, energy supplies and other social services and amenities.

Given this awareness and mandate, the United Nations Multi-Purpose Activities (UNMA) has extended the scope of its research programmes in this field.

The MA8 approach

Within Unesco, the Man and the Biosphere (MB) Programme offered an ideal framework for a pilot project to study, at a micro-scale, the complicated interrelationships which exist between the problems of an area and its developmental and environmental problems.

In fact, one of the underlying reasons for the launching of MA8 was the evidence that the pressures of population growth and movement and the demands of development have placed stress on man-environment relationships. These pressures and demands have important consequences for the environment as such, but more particularly for the sustained capacity of the different ecological regions of the world to support human populations at desired levels of welfare and well-being.

The essential integrating approach to such problems is found in the concept of a man-environment system, in which emphasis is placed on the characteristics of a man-environment system as a whole — its structure, its usage, the society which it supports, and the objectives of this society. In order to understand the functioning of this system, these chains of interconnection need to be traced out, 'modelled', and wherever possible made explicit.

One of particular interest in this respect is the capacity of a system to support people at particular levels of prosperity and well-being, and to support the very process of socio-economic development in its variety of forms. The concept of alternative uses of human and natural resources, and of guidelines to aid choice in decision-making, arises out of this approach. Strategies for natural resource use should aim to achieve forms of sustained production which combine optimal economic results with long-term ecological stability.

The man-environment systems of large countries are immensely diverse and complex and at the present stage of integrated ecological research it would be extremely difficult, if not impossible, to develop a complete model of such systems. Therefore, holistic approaches to the comprehensive study of complex man-environment systems are to succeed, examples of these systems must be found that are small enough to be modelled and at the same time representative of larger systems. Islands appear to fulfil these conditions, and the intensive analysis within and between which the interrelations of forces can be readily identified. Input and output flows of islands can be measured rather easily.

Among the MA8 Project areas, No. 7 focuses on ecological problems in the islands of Fiji.

Attention is given to three problem areas of special importance to island ecosystems, namely the management of environmental resources, the impact of external forces, especially tourism, and the impact of alien plants and animals. It is concerned in particular with the study of changes provoked by colonization, deforestation, commercial agriculture, urbanization, building of airports and tourism. The main emphasis is on man and change, rather than on resources and conservation, with the ultimate aim of providing information for management purposes.

Within the MA8 Project area of the eastern islands, two main topics were considered: 'Interactions between environmental transformations and the adaptive, demographic and socio-cultural needs of human populations', and 'The impact of environmental changes on man and his environment'.

The essential integrating approach to such problems is found in the concept of a man-environment system, in which emphasis is placed on the characteristics of a man-environment system as a whole — its structure, its usage, the society which it supports, and the objectives of this society.

The MA8 Project area has been planned and implemented within the context of MA8 field studies in various geographical and bioclimatic regions, such as those within the framework of MA8 Project area 1 ('tropical and sub-tropical forests'), Project area 2 ('mountain and alpine ecosystems'), Project area 6 ('mountain and tundra ecosystems'), and Project area 7 ('islands'). In addition, development and population built-environments have received considerable attention within the framework of MA8 Project area 11 ('human settlements')

The Fiji Project

With this overall background, Unesco-UNFA and the Government of Fiji joined efforts to carry out a first pilot project on population-resources-environment interrelation in the eastern islands of Fiji. The main aim was to reduce gaps in existing knowledge, to elaborate a set of reference information and guidelines for planners, decision-makers and research workers, and to develop further the methods needed for tackling problems in this field. Given these general aims, and the innovative nature of the proposed study, those involved in the planning of the first pilot project decided not to select an area with highly complex situations of population pressure, strong competition for natural resources, environmental degradation, a multi-sectoral economy, strong external impact and rapid economic change. Rather it was decided to start with a 'baseline' situation characterised by relatively simple interrelationships, that is, by the eastern islands of Fiji.

In agreement with the Government of Fiji, the eastern islands of Fiji were selected for the study, in agreement with the Government of Fiji.

The overall objective of the eastern islands study is to establish a baseline for an interdisciplinary team covering the natural, human and social sciences, the adoption of human and social sciences, and conservation, and the ultimate aim of providing information for management purposes.

Within the MA8 Project area of the eastern islands, 'Interactions between environmental changes and the adaptive, demographic and socio-cultural needs of human populations', is primarily concerned with the impact of the environment on man. This theme provides the main theme of the project, and the focus within MA8 for the consideration of the human dimension of research programmes. At the same time, the research aims to develop means whereby the carrying capacity of rural areas can be gauged, thus improving existing methods which tend to be too simplistic and are often unrealistic in their underlying assumptions. On the practical side, an attempt was made to assess the exact objectives of regional planning and integrated programming in Fiji, placing emphasis on rational management of renewable natural resources.

A second practical goal was to contribute towards a more satisfactory methodology for the study of population trends, particularly migration and its regulators, first of all in an island context, but also, by extension, in the agro-ecological sector of developing countries in general. In this way, it was hoped that the project would help in the formulation of guidelines for migration control programmes.

Field work under the project started in 1974 and ended in 1976. The project was headed by a Chief Technical Adviser. Unesco consultants undertook different component studies. About 15 research workers from various disciplines took part in the project. Among the fields represented were human and physical geography, demography, soil science, marine biology, forestry, agricultural economics.

The experts stayed in Fiji for periods varying from a few weeks to several months. Field research was followed by a long period of desk analysis, synthesis and reporting, ending in 1977.

In conclusion to this intrinsic merit and importance, the Unesco-UNFA Fiji project has played a unique role in the development of the MA8 Programme as a whole. This project is the first large-scale pilot research project, implemented and supervised by the International MA8 Secretariat in Unesco, to reach its conclusion. The project was exemplary for MA8 in several respects - the problem orientation, the design of an interdisciplinary team covering the natural, human and social sciences, the adoption of human and social sciences, and the formulation of guidelines for research, the dialogue with planners, decision-makers and the populations concerned at all stages, and the efforts to transform scientific results into practical information for planning and decision-making. Readers of this Technical Note will be able to judge for themselves the extent to which the project succeeded in fulfilling this exemplarity.

This Technical Note provides an overview of the Fiji project - its approach, its results, its achievements, its limitations and the way in which it has anticipated and contributed to new approaches.
its implications. The data described in this Note will mainly be of interest to tropical island states and those concerned with research and development in these countries. It is hoped, however, that the approaches and methods outlined in this Note will prove of wider interest - to those dealing with population/environment relations in rural settings in developing countries in general, as well as to persons in all regions seeking insights for integrated planning and programming in the fields of population, natural resources development and environment.

The follow-up project in the eastern Caribbean

In the light of the Fiji experience, the collaboration of UNFPA and Unesco has continued with the launching of a second-stage project on population, development and environment interactions in the eastern Caribbean. Field work in this second-stage project started in October 1979. The project has the active collaboration of the Institute of Social and Economic Research (ISER) of the University of the West Indies, in particular its Barbados branch. Studies are being conducted in several island countries, including Barbados, St. Lucia, St. Kitts-Nevis-Anguilla, and St. Vincent. The basic methodologies developed in the Fiji project to deal with a relatively simple man/environment system are being further developed to deal with much more complex situations of population pressure, migration, competition for scarce natural resources, the collapse of certain branches of agriculture due to the problem of diversion of labour inputs from agriculture into tourism, construction and other activities, strong external socio-economic impact and in some places environmental degradation. In practice, it seems that these Caribbean island societies have been able to surpass several apparent 'limits' to growth by recognizing in advance the existence of 'stress points' and taking appropriate action to overcome them. Consequently the second-stage project is also studying how such actions as, for instance, the family planning programme in Barbados and the adoption of soil conservation measures in St. Vincent, have influenced the population carrying capacity of these islands. By comparison with the Fiji study, the systems analysis and systems modelling approach, as well as perception and attitude studies, are receiving much greater attention. The overall development goals of many island Governments are to support their still-growing populations at the highest possible levels of employment and standards of living. The goals of the new project are to facilitate rational decision-making to this end.

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Introduction: the conduct and findings of the interdisciplinary Fiji project

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I. AN INTERDISCIPLINARY PROJECT

INTRODUCTION

The papers in this Technical Note constitute, in effect, the second general report of the Unesco/UNFPA Fiji project. This research project was carried out within Project 7 of Unesco's Man and the Biosphere (MAB) Programme (Unesco 1973). The purpose of this Note is to synthesise the wider conclusions of a project conceived as the application of scientific analysis to the pragmatic problems of population and development in an island context. The report comes as a late but not final stage in the overall publication programme of the project, the rest of which may briefly be presented as follows:

- The 'first general report' (Unesco/UNFPA 1977), which was a statement of project findings and recommendations prepared for the Government of Fiji. The full report has been widely circulated. A summary version, containing listed recommendations which did not appear in the full report, was made available only in Fiji;

- A series of seven Project Working Papers which were prepared before the first general report, and represent preliminary findings of individual project members. These working papers were basic to the construction of the general report;

- A series of three 1979 Island Reports, representing definitive detailed material on the islands of Koro, Taveuni, Kadavu, and Batiki and Labasa. One issue was devoted to the hurricane hazard and its impact;

- A 'third general report', to be published in 1981 by UNFPA, Paris, concerned with the results of work on soils, vegetation and land use. This will appear in both English and French.

Full bibliographic details of these publications and of other material arising from the project's work to date, are presented in the appendix to this volume.

In attempting a synthesis of the project's findings, it is necessary to draw on this large body of writing, as well as on the present series of papers, for while the latter synthesise important areas of the project's work, they do not synthesise the whole. The strategy adopted is first to describe the conduct of the project, and the means by which integration was achieved, then to discuss three specific aspects on which the project was able to make a useful contribution to knowledge and its application: the impact of man's activity on island resources; the carrying capacity question; the vulnerability of small island populations and their resources. Two larger aspects: the theoretical framework of the project, and the question of designing guidelines for resource use and population policy in small islands, are the subject of substantive papers at the end of this Technical Note.

THE CONDUCT OF AN INTERDISCIPLINARY PROJECT

Project design and the selection of personnel

The design of the project was prepared in Suva and in Paris in 1973, and reflected a compromise among the three major interested parties - the United Nations Fund for Population Activities (UNFPA), the Man and the Biosphere Programme of Unesco, and the Government of Fiji - for a study of the problems of the seriously marginalised outer islands of Fiji. This compromise of objectives preoccupied throughout the conduct of the project and its reporting programme, and has underlain some difficulties encountered in the English and French. The project has been perceived differently in different quarters, both within Fiji and internationally. The project

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This was achieved through the Island Report series, and in the present NAB Technical Note. However, it was also laid down that all members of the project were free to draw on the work of others, given acknowledgment in every case, and with prior consultation whenever possible. The tradition of oral tradition and freedom has proved an invaluable aid to integration.

The real value of the continual informal exchange of views and material achieved during group work on the islands, and in Suva, became apparent at the formal meeting held in Suva in August 1976 to discuss the content of the first general report. Almost half the project group was present. A first draft of almost half the report had been prepared by the Chief Technical Adviser from consultant documents and his own material. The design of the second and more important half of the report remained to be discussed. There was almost immediate agreement on all material issues concerning the project's recommendations; the active discussion was on matters of detail. Drafting of the second half of the report, and re-drafting of the first chapters, were divided up among the group. A complete draft report was available within four weeks of the meeting and circulated for comment. After discussions in Fiji in November 1976, this draft report was then reworked into the final report, published in 1977 and published in August 1977 after clearance by the Government of Fiji.

The present report

Papers for the Island Report series and for the present collection have been prepared without the advantage of close collaboration. Even when discussions have taken place and some drafts have been circulated well in advance of their completion in final form. Original papers for this report have, however, arrived late, and this introductory paper, like the theoretical paper below, has had to be prepared in advance of their receipt, with only partial knowledge of their final content. This section, a late amendment to the Introduction, therefore records the surprise and pleasure of the editor that so large a measure of integration has in fact been achieved.

Two main themes emerge clearly. The papers of Bayliss-Smith, Beddow and Hardiner are in different ways concerned with population and economy, and with different perspectives on the formation of populations to the real and perceived opportunities offered by the environment and economy of the islands. The papers of Latham and Skolnick are also concerned with the environment and its resource content, and with the impact of both natural and cultural external forces on the islands and the seas around them.

Several of the papers seek to go beyond empiricism into theory, and most draw on data and literature from outside Fiji. It is here that the congruence of ideas is most marked, especially between the essential conclusions of Bayliss-Smith and Beddow on the one hand and of Brookfield and McLearon on the other. The present introductory essay cannot do full justice to this integration of ideas, because time does not permit its complete re-writing after receipt of late papers. Nonetheless while the overview presented in this paper and in the theoretical paper below is essentially descriptive, it seeks to present the collective view in surprising measure.

The individual contribution of these papers is important. Some will be controversial, and hopefully stimulate dissent. Some bring forward important new evidence, though the greater contribution is of a type which is necessarily what has already been presented elsewhere in detail. More significant than the parts, however, is the collective contribution of the whole. Though far from fully co-ordinated, here is the considered response of a group of social and human scientists to the empirical problems presented by a particular region, a particular area, a particular set of natural environments and a particular set of socio-economic conditions. There is, in fact, quite remarkable congruence, which can be brought together in part in the four themes which are discussed first in this paper. It is an Introduction and then in the final paper.

II. THE IMPACT OF MAN’S ACTIVITY ON ISLAND RESOURCES

The Environment Game

In an inaugural lecture, Douglas (1974) likened man’s interference with his natural environment to a game played against environmental processes whose responses, and even whose nature, are largely unknown. Every human innovation on the landscape has environmental consequences, and through feedback mechanisms to produce quite unexpected results. A central objective of the Man and the Environment Programme is to
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One of the more significant trends in modern environmental reasoning is the growing realization of how much can be learned about the present from study of the past. Once it came to be realized that the same processes that caused a given phenomenon to occur could be separated from the effects of climatic change in the palaeohistoric record (e.g. Seward 1944; Iversen 1949), the groundwork was prepared for an increasingly productive collaboration between palynologists, geomorphologists, prehistorians and latterly also historians and climatologists in work applied to a range of problems from the origins of agriculture and of anthropogenic grasslands to the elucidation of the cultural and economic consequences of past patterns of climatic variation (e.g. Gribbin 1978). The record left behind by the moving interrelationship between human activity and environmental variation has increasingly shown the overriding importance of the human factor except in marginal conditions where macro-climatic variations through time have been sufficient either to create or destroy the conditions for particular forms of human activity, such as agriculture. Thus the impact of man's intrusion, of growth in his numbers, or of changes in his technology can thus be read and often measured from thechanging viability of land in swamps, lakes, sediments and on the landscape. The value of this evidence in the interpretation of the human component of the on-going processes of change is important in forming a more realistic estimate of the long-term effects of contemporary changes, often provides a corrective and an interpretative source of information, and assists in the design of management strategies for long-term harmonization of human activity with its dynamic environment. In the closer case in point is the overwhelming consensus provided by the background papers prepared for the 1977 U.N. Conference on Desertification: while critical stresses emerge under short-term climatic variation, man is himself primarily responsible for the environmental degradation that is called 'desertification', and is also able both to reclaim much of what has been lost and to manage a recalcitrant environment so as to prevent its renewed deterioration.

Three papers in the present collection draw on the past for interpretation of the present. Molaison discusses the spatial and temporal variability of external controls on tropical island ecosystems, and notes the importance of former changes in sea level in any understanding of the geomorphology of small islands, and hence in the decision of whether or not they may exceed any normal range of variation in these mean conditions. In so doing, he emphasizes an underlying similarity in the small island ecosystems that they are peculiarly open to the effects of external forces, and that human agencies have effects on their fragile stability which exceed those experienced in continental environments. Without sailing on this similarity of islands, Latham and Denis call attention to the unusual degradation of environment experienced on certain islands in eastern Fiji, and estimate erosion rates on certain catchments which are in the high range by general standards; they therefore suppose that the effect of human interference was unusually dramatic in these vulnerable environments.

Latham and Denis are concerned with the evolution of an extreme example of environmental degradation: the formation of a soil-vegetation complex characterized by basaltic soils on the uplands and truncated soils on the slopes, coupled with very heavy accumulations of establish of a seemingly-stable vegetation complex dominated by ferns and casuarina on soils of extremely low fertility. This is, however, contrasted with the fact observed that this vegetation complex could be maintained, and this contrast and its introduction of contrasts between quite extreme degradation on an island of Pleistocene volcanic origin, where comparable human interference is not believed to have occurred, and on an island of similar age and composition of the parent material of soils, and by small but significant differences in the type and age of a completely contrasting result in terms of the present soil-vegetation complex of each. Does this comparison of the extant vegetation reflect the extent of a controlled experiment over an occupation period between 2000 and 3000 years? It would then follow that management strategies for tropical island cannot be undervalued, and that must be made specific to the particular environmental region and quite local climatic conditions. Argument based on world-wide evidence concerning overriding influence of human impact over variation in natural conditions might seem to require reconsideration in the light of single deviant case where the contrast is of such magnitude. Such deviant cases are also to be found elsewhere.

From the Fiji project alone, this question has no less interest, and much more importance. In the final paper, Vulcanism on the 'stable' Island has continued into such recent time that it may be said to have a very marked influence on the comparison; soils on part of the 'stable' Island have certainly suffered severe truncation within the present generation and it may be that the impact of former degradation is masked by deposition of new volcanic ash within the past 1500 years. Population on the 'stable' Island may never have grown to levels at which pressure on environment equaled that historically imposed on the 'degraded' island. Alternatively, the difference between andesitic and basaltic parent materials, and between undinear and minimal liability to drought may be sufficient explanation of the differences. Perhaps the greater size of the 'stable' Island is also important, for neither its size nor its shape would have been greatly modified by Holocene sea-level changes. Nonetheless, this is a question to be carried over into the future to be studied in more detail, either by examining the similarity of a system and the Pleistocene chronology of vegetation change and sedimentation is evidence that these similarities exist, and are significant when considering the management of present environments. remarkable that on the results of such inquiries as the project will hopefully make on the Fiji, and on the far more solid evidence concerning past environmental changes which it is believed to be possible to establish in the Caribbean. One further aspect of changing man-environment relations in climate is of significance in the present context. Latham and Denis take special note of the stable high fertility of the uplands of the 'degraded' Island of Rakah, and suggest that this is derived from downwash from the degraded soils of forested and reed-clad catchments. The evidence of modern crop yields, which show no significant difference between swamp and upland water from degraded and undegraded catchments, must cast some doubt on this suggestion. The terrestrial environment is highly important historically and is the Fiji. A recent study of the 19th century settlement pattern in the focal delta of Viti Levu (Tarry 1977) suggests that this region sup-
DISCUSSION OF TWO PAPERS

Two of the papers in this collection touch directly on the question of measuring carrying capacity of islands in terms of human population; a third, simpler, method of calculation was adopted in our first general report (UNESCO/IMFFA 1971). Radically different approaches are adopted. Hardaker reaches the question as a by-product of a linear programming model of the agricultural economy of the island, using the project's material from Tavua as the most readily available data. Bayliss-Smith considers his method to be a by-product of his new general utility theory to be evolved. Bayliss-Smith candidly notes that his method does not take account of large imports of imported energy; Hardaker observes that it is not conceivable that the large capacity figures reached could be achieved without radical structural change in the whole economy of the island. Neither adopts the modification introduced in the first general report of reducing the capacity population by 0.5 to allow for necessary living space. More specifically, while Bayliss-Smith allows for productivity above subsistence needs in order to support social prestation, or alternatively additional unproductive persons, he does not attempt to evaluate the multiplier effect of additional non-agricultural population that might be supported. It is clear that Bayliss-Smith does Hardaker incorporate this element.

A WIDER VIEW OF THE PROBLEM

No criticism of either author is implied in what is said above, but it must be admitted that the problem of quantitatively relating population to land is carried only a limited distance forward, even though Bayliss-Smith's concept of welfare is an advance of major conceptual importance. Yet it is highly important that we do take it further, and quickly. A recent United Nations study of the future of the world economy (Leontief et al. 1977) calls both for a major increase in the yield of land already cultivated, but also for a 30 per cent increase in the cultivated area during the coming quarter-century if the population/food balance is to be maintained, or improved. Leontief and his associates regard this as feasible, yet the quantitatively

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The evidence would seem to be wanting. At the same time, climatologists such as Hay (1977) and Cribbin (1976) warn that increasing climatic variability, and the prospect that this will extend to the continent through the coming quarter-century make reliance on "normal" yields as a basis for prediction of food production increasingly uncertain. Cribbin warns that the possibility of 'bad years' is likely to increase, with effects on output as great as the present estimates of global levels and much greater local variation. In these circumstances, the notion of standard population needs to be enlarged to take account of great variability in production at the local level, and needs to incorporate such possibilities as relief from buffer stocks held elsewhere, and also the greater use of 'famine foods' of local origin. Such projections as those of Leontief explicitly embody the concept of carrying capacity at regional and global levels; the climatologists would at the same time seem to be warning that a much larger error term needs to be built into the projections, and that world food policies need to be re-evaluated accordingly.

Defining the question

The answer becomes positive only if the question being asked of the data is clearly defined. Any island, any region, has an optimal change, and for many there is also a development policy, however broadly defined. Some areas are already over-populated, others under-populated; for most it is possible to project population trends on either a non-migration basis, or on the basis of any given set of assumptions concerning future migration. The question may be posed in terms of the previous population, or a future population, or a past population under which the actual conditions can be established by historical record. The appropriate question then concerns the ability of supporting the 'target' population, at a target level of welfare, from the resources available and within the existing or planned economy. Necessary modifications to the plan can be fed back.

We must refer, however, to the important ancillary question of variability in both ex-
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Replise-Smith's analysis - to take a given population and determine the quantity and area of resources required for its support under a given system of technology and spatial organization. The Island of Barbados, which supports a quarter of a million people at possibly a higher mean level of welfare than the equal-sized Fijian island of Tavua, with only 7000 people, might be a good place to begin such an inverted inquiry.

IV. THE VULNERABILITY OF ISLAND ENVIRONMENT AND POPULATIONS

A QUESTION OF SCALE

Assumption and evidence

It is widely argued, and supported in some of the project's reporting, that islands are particularly vulnerable to external forces, for the barrier that separates them from other lands can become a highway. Vulnerability would seem to entail two sets of conditions, both related to small size. First is the rapidity with which any new introduction can spread over the whole of a small landmass or population in the absence of remote refuges which innovations are slow to reach. Second is the limited size of the genetic pool itself, which greatly limits the ability of island flora, fauna and people to absorb and contain the impact of new forces. A second lack of diversity, which reduces 'ecological resistance'. Such conditions favour devastation by initial onslaught.

The most fully documented instances, to some of which we shall refer below, concern the impact of introduced diseases and populations with out immunity. A classic case is the entry of malaria into Mauritius in the 1860s (Morgan 1970). There, the population of the largely immigrant population was drawn from malarious areas and the disease was therefore present, there was an increase in the number of Fijians. Another case is of A. funestus introduced to the island. Spread of the disease was extremely rapid, killing one fifth of the population of the capital in 1867: subsequently it became endemic, changing the whole mortality and morbidity patterns of the island, and restructuring the settlement patterns by placing a premium on the central plateau which remained immune until early in the 20th century.

In some instances the impact of innovation was so severe as to destroy either the population or other elements of the fauna, or flora. In others, a proportion survived and adapted to the innovation. Given that islands are assumed to be so vulnerable, it is remarkable that so much has survived. We seem to have a contradiction. On the one hand islands may be viewed as a set of small islands which individually can readily be snuffed out, whereas a large configuration is more difficult to extinguish. On the other hand, islands continue to be viewed as places in which such that endemic has been able to survive or has proved adaptive, and where 'traditional forms' have been protected by isolation from forces that have destroyed them elsewhere.

This latter issue is faced more squarely in a later paper in this collection, but here the problem is introduced in a more pragmatic context. If both conditions are true, even in part, then the co-existence of such traits demands explanation. In order to discuss this question, we shall have to depart rather further from the 1860s in Fijian history, and from the Fijian evidence, than in the preceding discussion. This discussion prefaced a number of the papers which follow.

The case of marine resources

Although this is primarily a question concerning the land, it will be helpful to begin with the sea. Salvat's paper in this collection ends on a question. Perhaps this is for a conclusion that may link Salvat's theme to that of other papers. One way in which the marine resources around an island can be differentiated is through their mobility or immobility, depending on whether the living marine resources are specific to particular niches in the ecosystem, or widely distributed. This is so even though the species concerned are widely distributed between islands across a range of genetic criteria. The distinction is only that the environment of other ecosystems must be possible, but not within a short time span. Other species are migratory, depending on island resources for part of their sustenance, or during periods of their life cycle, but not during their lifetime. In other cases the small area of land and the plants that they use large areas of land for the cultivation of organic products which are exported, thereby maintaining large and varied imports. Especially in the Caribbean, present levels of welfare demand these imports, and could not be satisfied by subsistence production of however intense a nature. Economic terms of natural resources the deficit is therefore substantial. Even in Fiji some 25 per cent of imports come from the sea, a deficit which in this instance a substantial reduction in the deficit would be possible by more rational allocation of national resources. (Bolshoy 1977), there remains a necessary import fraction if present welfare levels are to be sustained.

To use the standard population notion in this way might provide a more realistic measure of carrying capacity in the modern context. While it is important to know that a given territory can, from its own resources, support a calculated number of people in basic needs, or in basic needs plus a given income, this tells us little about the real carrying capacity of any portion of the modern, interdependent world. We call upon external resources as soon as anything beyond basic subsistence needs is involved.

It follows from this reasoning that the carrying capacity of regions which depend on trade, such as Great Britain or Kahara, might be below their present or historically recorded populations. But there are comparatively few such regions in the world; in area terms, the deficit regions of the world are supplied mainly from low-intensity regions which are in time to provide food to people, support many more people than they presently carry. Thus the 'underpopulation' of some regions is more real in the sense of the interdependencies of the modern world which depends at least in part on trade, and enjoys at least some division of labour between producers and non-producing specialists. Neither Hardaker nor Bayliss-Smith, nor any other writers on this topic, really come to grips with this problem, yet in so far as the carrying capacity of the world under any given technology is the summation of the carrying capacity of all its parts, the degree of interdependence under which the surplus production of some areas supports the surplus population of others is a vital element. A more realistic measure is essential for rational planning of environmental management. While in the beginning should be in the inversion of...
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Elemental analysis of each group are clearly more vulnerable to predation than others. The mobile whales, turtles, and perhaps also the large tunas are clearly vulnerable. So also are the inmobile Phoebastes monopterygius, Tridacna maxima, some other molluscs and the dugong. Salter's discussion implies that many of these species would be equally vulnerable were they not protected by hazards to modern technology such as coral heads in the lagoons. There is a further group of species which seem to have survived heavy predation, and yet remain a resource. These include the trepang, the fish of the outer reef slopes, and the skipjack or bonito. Moreover, even though some resources have been devastated the destruction is not often complete; given time, or breeding, stocks can be re-established from very small relic populations.

Vulnerability of island environments

Though this discussion is concerned mainly with living creatures, it is important to note the degree to which island environments themselves may be vulnerable. Phosphate or bauxite mining may not be an extreme case of destruction, leaving only a mass of broken coral limestone in their wake, yet the land itself will remain until it will become re-vegetated. In the case of Lakeba, Fiji, already discussed above, the ancient vegetation pattern and its flora has been transplanted through centuries of fire, while most of the uplands have thus become worthless for farming a new use for them has now been found in the planting of Pinus caribaea. Meanwhile, swamps have been created and continually replenished in the valleys, and became a highly valuable agricultural resource once a technology for drainage and controlled irrigation was, at some unknown date, imported to the island. This is a long-term view, but the same line of argument can also be applied to the shorter term. Lay's (1977) dramatic attention to the manner in which erosion of one land unit can lead to enrichment for agriculture of another, is a Mexican example.

None of this is peculiar to islands. There are, however, two elements that are distinctive. The short length of most island catchments has the effect that most eroded material is carried into the sea, rather than being deposited. This means that coastal zones themselves are very vulnerable to violent attack from the sea, and to even small changes in the relative levels of land and sea; on islands this assumes larger relative significance than elsewhere because the coastal zones form so large a proportion of the whole.

Vulnerability of island biota

Here we would seem to be on surer ground, for the biota of many islands has been wholly transformed by human activity or by animals and plants unwittingly or unwittingly imported by man. In eastern Fiji, for example, a great number of weeds has been imported, to the detriment of modern agricultural activity; not all weeds have yet reached all islands, and it is regrettable that the project did not have the resources to embark on a fuller study of this aspect, which was noted early in the programme. Greater transformations have taken place elsewhere, particularly in the Caribbean where a high proportion of the original total of recorded species extinction in the last few centuries is located, and where many new species have been introduced (Barris 1965). Yet even in the most heavily impacted islands some endemic species have survived.

Once again, however, this is not specific to islands. A continuing and unresolved debate surrounds the roles of climate change, and of man-the-hunter, in the rapid disappearance of a number of large mammals. The more recent destruction of the herds of bison than once ranged the north American grasslands, or in the reduction to small numbers of the large and varied stocks of wild animals that were found in east Africa a century ago. While some island species have vanished quickly - the flightless dodo of Mauritius is only the most famous example - this fact by itself does not establish a case for special vulnerability of island biota. It is true that island species provided, and sometimes still provide, refuges for endemic species until some predator or competitor has been able to reach them. But predators with teeth did their work no more quickly on islands than did predators with guns once the latter reached the continental interiors.

The question of vulnerability can now be posed more clearly. Islands are seen as more vulnerable because they were the home of a large number of endemic species of plants and animals that evolved during isolation. In terms of the number of species destroyed or threatened, islands are distinctive and this is important. Islands are also more vulnerable to storms brought by other external variation around mean conditions than larger land masses. In quantitative rather than qualitative terms, however, much greater destruction has been wrought in modern times in the continental interiors than on islands. The question of scale is important, but in comparative terms islands merely exemplify what has happened on a much larger scale in other environments.

Island populations: fatal impact

Concern over the fate of islanders infected with disease to which they were not in any way immune emerged in the 18th century, and though the concern did little to save the islanders from intensification of the 'fatal impact' it has continued into modern times. While true isolation constitutes protection, it also makes the isolated population unusually vulnerable once the isolation is breached. There is little historical evidence to support the view that the impact of external forces on islanders has been uncommonly severe. Most, if not almost all the recognized cases of extermination of human populations refer to islands. The Quichuas of the Canary Islands were early victims though, like the Caribs of the eastern Caribbean, a very few of these people survived. The northern Arawaks of the Greater Antilles seem on the other hand to have been destroyed totally, in the space of less than a century. Other examples include the Tasmanian short-fish, the people of a few islands in the Pacific, and the Bororo colonists in Guayana who, from a real point of view, were as much islanders as any other of the world's vanished populations.

Taking these larger instances into account, it is perhaps surprising that so much attention has been focussed on the Pacific, where the evidence is much less clear. Some islands have been depopulated, but finally by migration rather than extinction. A major decline in numbers certainly took place in the large majority of Pacific Island populations over periods that began and ended at varying dates, and important fluctuation is recorded. However, an important part of the evidence concerning the scale of depopulation revolves around early population estimates. McArthur (1967) has suggested that these early estimates in detail and concludes that very limited reliance can be placed on them. Moreover, numerous islands in central and southern 18th century under-numbered the island populations, so that the extent of the decline has often been over-estimated and the original definition of 'initial populations, and under-estimation at the lowest point in the curve. Some islanders, however, suffer very severely, and this can be demonstrated from the historical record. One such is Anetan in the New Hebrides (McArthur and Yatey 1968; McArthur 1977), where archaeological and as documentary evidence has been examined.

Population numbers are fairly reliably estimated between 3500 and 3800 in the 1850s. Decline, at first rapid, continued for many years, reaching only 195 in 1957, a loss of almost 95 per cent. The major event was a devastating epidemic of measles in 1850, shortly following a severe hurricane, and followed a few years later by epidemics of diphtheria and whooping cough. Circumstances favoured high mortality, for the population had been recently Christianized, concentrated into villages, and assembled regularly in crowds during church services. There is no evidence which produced almost ideal environment for the rapid dissemination of disease borne by droves of infected individuals. Overall mortality was more severe than that of males, so that as there was already a surplus of males, the sex ratio of the population to reproduce itself was disproportionately diminished.

The cause of the introduced disease is unlikely to lead to sustained depopulation unless it strikes heavily at the present and potential reproductive males. Such is the case of anestom, where infant males were of 'least account', the chances of a female child surviving the death of its mother would be less than that of those of a male child, with cumulative effects into the next generation (McArthur 1967, p. 30). It would seem that this was the situation in a large number of Pacific societies, so that epidemics or other causes of unusual mortality which impacted the young adults more severely than the rest of the population would have a lasting effect. Epidemics were not the only cause of high mortality. Severe hurricanes led to famine, and famine may also have been responsible for the deaths arising from the dislocations of warfare than the
killing itself, massive though this sometimes was in countries such as Fiji. Nor is it certain that all diseases were necessarily introduced; social upheavals which accompanied the destructive wars of the 19th century and subsequent famines in some of these island countries might have increased the mortality of the population. 

**Islands and mainlands**

Did islands suffer an unusually catastrophic experience? The one case in which a wholly affirmative answer can be made to this question is that of the Arawak of the Greater Antilles, whose destruction has been very fully documented. However, the numbers in this case may have run into millions, and the disaster seems related to the severity of the colonial impact, and not to small size of the geographic area. The data from central Mexico, which is hardly an island, bear out this contention. On the basis of an exhaustive study of the available records, S. H. Cook (1963) estimated the population just before the Spanish conquest at 25.2 millions. By 1619 this had fallen to 16.8 millions, then to 6.3 millions in 1648 and to only 1.1 millions in 1665. This is a decline of slightly over 95 per cent in less than a century and over about the same period as the recorded decline at Ansemyt. Loss of population was greater in these areas, however, with social dislocation, for men was displaced from his lands by domestic animals introduced by the Spaniards over wide areas.

**A model of total destruction**

There was a world of difference between a decline of 95 per cent and one of 100 per cent; in the former case there remains a possibility of re-establishment either autonomously or through intermarriage, as was the case in Mexico. In the event of total destruction, repopulation can come about only by replacement, as happened in the Antilles, but almost nowhere in the modern Pacific except where people were removed in order to be replaced by estate workers. It is worthwhile to cite one explanation of total destruction at length, for it provides a sort of model of what might have occurred in many situations, but did not do so. The example is that of the former inhabitants of the central desert of Baja California, where extinction took place over quite a long period, not being complete until the beginning of the 20th century. Asmann (1939, p. 204-205) explains it in these terms:

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The final sentence in this quotation is significant in that it paves the way for other conclusions. McArthur (1976) has calculated the survival possibilities of very small populations in complete isolation. Some stochastic processes assume. Some model populations grow; others perished. Her models do not take account of variations in the environment or in subsistence technology, but they do demonstrate the high risk of extinction among small populations in isolated settings.

Jones (1977) has applied this reasoning to the contracted fate of the Tasmanian aborigines and those of Kangaroo Island off the South Australian coast, after these islands were separated from the mainland by the Flinders transgression between 12,000 and 12,000 years ago. The Tasmanians remained barely viable in a poorly provided territory for 500 generations before the surviving population of some 4000 was speedily destroyed at the hands of British colonists. The Kangaroo Island population perished much earlier, and other new islands created by the transgression seem to have been abandoned before they became totally isolated. On the basis of a wide search for evidence concerning the interrelation of population numbers with the resources of their territories, Jones concluded that a minimum viable population for maintenance in total isolation was about 500, and that islands without the resources to support this number were the islands to be abandoned, or depopulated. Questions of external impact were not involved in these estimates.

**No man is an island**

The key to the enigma is all contained in what is written above. The people of Baja California lived on a peninsula, were almost as much isolated islanders as were the Tasmanians. In their isolation they survived better than the aborigines, but concentration into fixed settlements by Spanish missionaries created the conditions for disease transmission which led to their destruction. Other, less isolated people in northern Baja California barely survived, for they remained in contact with tribes beyond the range of Spanish rule. In central Mexico, the minimum population was still quite numerous, and less impacted groups were adjacent in central and south. The Arawaks had no such support, nor the Caribs whose demise was much longer delayed. In mainland Australia, many population groups ceased to exist, but individuals were able to join others in the retreating refuge of the vast inland. In peninsular Malaysia, the Orang Asli could retreat into the interior jungles, while the surviving Bushman of southern Africa could retire into the Kalahari desert. Intermarriage with the invaders also became available to all these groups.

**Pacific islanders were seawarriors. Until very modern times most islands possessed sea-going craft. The sea that brought disease-bearing ships, labour recruiters and land grabbers had for centuries carried men and women between islands. There was no need to sit at home and die. If wives were unavailable at home they could be found elsewhere; people moved from disease-infested sites; once a reasonable degree of immunity to the new diseases had been established a larger world lay available, and the genetic pool was not limited by the bounds of the immediate environment. In this volume, Bedford takes up the story of migration and stresses its vital role in the modern demographic processes. It is the means by which islands are depopulated and repopulated in the modern context. In an earlier time, the facility for migration may have been responsible for demographic survival. In this respect the Pacific islanders may be the exception: insularity is not measured by the fact of island environment, but by the ability or inability to move.**

**Conclusion**

Islands are canals, to be snuffed out one by one only for those island-living species which are territorially bound and unable either to adapt to, resist or retire in the face of innovation. The concept of insularity would have had a little meaning to the Pacific islanders as to the Vikings: the sea was as much part of their living space as was the land. It is not insular environment that makes an island population vulnerable in size, but the adaptive and mobility characteristics of the population concerned, and the resources it is able to draw on. Once that can move, retire into or recruit from other environments have far greater survival capacity than those that have no choice but to remain passively where they are.
V. VARIABILITY OF EXTERNAL CONDITIONS

CONVERGENCE FROM TWO APPROACHES

Two papers

Two papers in this collection, the paper by McLean and Brookfield's theoretical paper toward the end of the volume, converge toward a two-part conclusion about islands which may have greater relevance to the real problems of island planning than the classic notions discussed above. Brookfield discusses the dependence of modern island populations on external economic conditions and decision-making. McLean elaborates in detail the variability in external physical controls on small island ecosystems, and comments that island environments also are subject to externalities beyond their control. He goes on to suggest that the constant rejuvenation of the natural systems that follows from variation in external conditions sustains diversity and sategony, and that this condition parallels the constantly renewed opposition to external forces in the human sphere described by Brookfield. The argument is fully elaborated by McLean, and need not be discussed further here.

As for our second approach, however, there are important implications. If the variability of external conditions is such that notions of land use are inadequate in physical and human domains alike, then what we should be seeking is the means by which constant, or from-time-to-time change and variation is achieved. This applies both in our interpretations of the past, and in the design of policies for population, economic and environmental planning. The point is taken up in the final paper, but some elaboration is useful here, especially in regard to an aspect of variability that is touched on at several points but nowhere treated in detail in the present collection—the impact of natural hazards, both the environmental and socio-economic contexts.

Extreme events and small islands

McLean details a very wide range of natural forces which impact islands in so variable a manner that means based on a comparatively short period of time are of very limited value in describing their effect. They include seismic forces and volcanism, sea waves from all points of the compass, tsunami and see surge in hurricanes, hurricanes and gales themselves, and drought which—as Latham and Dennis also show—can have significant ecological effects even when of quite short duration. There is also a rise in sea level in the past 70 years and the disputed possibility that this may accelerate; the effect of this can increase erosion and liability to hazard from the sea, and on low islands there are also more serious effects on the position and size of the fresh water lens.

The project made a special study of the hurricane hazard in the eastern islands of Fiji, and this is very fully reported in Island Report N. 1. Two out of four hurricanes which struck Fiji in 1972-75 had a serious impact in the eastern islands, destroying crops and houses, and so damaging coconut palms as to cause a prolonged break in the production of copra which was almost the sole income source of the islands concerned. One of the hurricanes also caused severe loss of life through the founding of two inter-island ships. The immediate distress was great, but relief operations by Government averted serious food shortage and helped make good the loss of shelter. What Government did not and could not do was make good the loss of income, which went on for much longer and was made worse by a serious depression in the price of copra beginning in 1976 and continuing through the end of 1976. A price-stabilization scheme introduced in mid-1975 provided some assistance but the necessary producers whose trees were yielding only a fraction of their normal production

Horrors are the major present hazard in this region, but drought can also cause severe distress, loss of production, and in some islands actual shortage of water. It is not uncommon for water to be carried by ship to drier islands from those with perennial streams. All these hazards have been made more severe in one sense by social and economic change, for while the actual risk of famine is removed, dependence on copra, increased water use, and re-location of villages onto vulnerable shorelines have all increased both risk and dependency.

The project expressed concern at this condition, and some of its strongest recommendations concerned alleviation of risk. They recommended crop diversification as a long-term strategy, together with the relocation of settlements away from the most exposed coastal locations onto higher ground.

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They also commented on the location of much modern tourist development, on one of the eastern islands and much more elsewhere in Fiji, in very vulnerable positions close to unprotected or poorly protected coasts. They did not, however, comment on the question of insurance against hazards; where 'normal' conditions are hard to establish it is not easy to fix a normal level of production for purposes of compensation. We return to this question in the concluding paper.

Variability as a constant condition

The argument must return, however, to the same question that has been asked above, and is asked again in later papers: are the conditions affecting islands notably different from those of other environments? Is not variability a constant condition in most of the world's environments, with the exception only of the most extreme—the cores of the cold and hot deserts?

In this respect, as in other places in the collection, the editor may differ from some of his colleagues. He would maintain that McLean's insistence on spatial and temporal variability in the external conditions of environments is an argument that could fruitfully be applied in many places other than tropical islands. There is certainly one respect in which islands experience distinctive problems, and this is in their exposure to the sea, and to the wide range of hazards, changes and unpredictable forces which are imposed onto coasts from the sea. In many other environments these are either marginal in significance, or of no significance. In other respects, however, the argument of this collection is applicable to most of the biosphere: it is time to pay much greater attention to the variables which lie around mean conditions which are widely taken as normal—even though based on only a century or so of observations.

RELATION OF THE PROJECT TO THE MAB PROGRAMME

The Fiji study was designed as a pilot inquiry within MAB Project 7. Although there was already discussion of cross-fertilization between projects, it was not expected of the Fiji study that the team would be so preservative as to address itself in conclusion to the programme as a whole. This has, however, become the purpose of several writers in this collection, and of the editor.

The justification for such presumption lies in what is written above, and in the nature of Project 7 itself. The island programme is not concerned with one type of environment or human use system, but with a set of different environments and human use systems which in fact represent a wide range of conditions found in the world as a whole. The theoretical justification is presented below, and a new paradigm for the study of man-biosphere relations as a whole is proposed and discussed. In the introduction, however, the ground for later argument has been prepared by a review of four specific aspects of the problem. Each arose in an island context, but each has far wider application.

It has been argued that discussion of islands can never be complete without also drawing on evidence from continental situations. The converse is also true and island studies are justified at a world scale only by their realistic incorporation of wider considerations. The world is one, and the ultimate justification for the study of one small part of the total complexity must lie in what such study has to say that is of value to the world as a whole. In the financial and problematic context of the first decade of the last quarter of the 20th century no other context is possible.
A central scientific object of MAB Project 7 has been the development of more meaningful ways in which to assess the human carrying capacity of spatially defined parts of the biosphere. For various reasons, the most important of which have been reviewed elsewhere in this Technical Note, small islands were regarded as ideal research laboratories in which to examine the measurement of population potential. It should be noted that, at first sight, that 'smallness' per se is not a particularly useful attribute when studying processes which determine the actual size and structure of human populations. Most of the standard techniques for measuring levels of fertility, mortality and migration are explicitly designed for populations numbered in tens and hundreds of thousands. Application of the various rates and ratios derived from real and hypothetical (model) populations to the study of demographic behaviour in groups numbering a mere 200 or so people can lead to serious problems of interpretation. Wide variations in indices for a particular population over time, or between small populations at a given time, may reflect nothing more than chance fluctuations in the incidence of births and deaths. Small populations do not behave in the same way as large statistical aggregates. The smaller the population base the greater the probability that random variations in vital events will affect population structure and patterns of growth. Gaunt (1971; 1975) and others have outlined a simulation model for projecting future population numbers less than ten. They note that 'the conventional technique of population projection needs to be translated from the deterministic procedures which were designed for large populations into probabilistic stochastic processes which nevertheless retain the same demographic logic.' (McArthur et al., 1976, p. 308). However, in modelling exercises such as these the population has invariably been 'closed'; no additions or losses through movement are permitted. They represent true isolates, populations which have never been found even in a world of islands.

It has been established that the relative importance of population movement and natural increase/decrease for structural and numerical change varies according to the size of the spatial units under study (see, for example, Web 1963 and 1976; Clarke 1972 and 1976). As population movements occur over short distances the great majority are contained within large area units. The smaller the spatial entities used in the inquiry, the greater the relative importance of population movement. This has obvious implications for the emphasis that may be placed on particular demographic processes in the analysis of population change. When dealing with large countries (such as the USSR, India or China) attention will inevitably focus on natural increase as the main component of population dynamics, whereas at the island or micro-level there is likely to be more concern with human mobility (Clarke 1976). To put it another way, 'the relevance processes vary according to the scale of analysis chosen' (Harvey 1959, p. 386).

By opting for a field site comprising a region of what most scientists would regard as 'very small' islands, the architects of the MAB Project 7 pilot project in eastern Fiji virtually demanded that the study of population...
ion movement assumed highest priority in the demographic inquiries. Two dimensions of 'smallness' in 40 inhabited islands in eastern Fiji are given in Table 1. Over half the islands had under 400 residents at last census (1976) and 40 per cent of them are smaller than 10 km² in area. The median population and area were 320 and 12.6 km² respectively. Ogyo one island had an area in excess of 200 km² and a population that was greater than 5000. Although the islands are scattered over a large expanse of ocean, inter-island population movement has been common for centuries. In recent years the net effect of this mobility has been to accelerate population losses from the region - a trend which leads Brookfield to comment on p. 185 of this Technical Note that 'changes in natural trends due to declining mortality, the impact of the family planning programme and fertility declines from other causes, are overlain completely by migration'. In the light of these circumstances, it is hardly surprising that the demographic component of the Fiji project was heavily biased towards analysis of mobility. Not only was the problem perceived to be one of the most critical constraints to economic and social development by project personnel and some administrators and planners in Fiji, but the other important 'regulator' of recent demographic trends, fertility decline, was already the subject of intensive inquiry under the auspices of the World Fertility Survey. With fertility already under scrutiny, the demographic component of the Unesco/UNFPA Fiji project focussed on population movement. Some detailed studies of reproductive behaviour and contraceptive use were carried out at the community level, and a very general survey of recent mortality trends was prepared as part of an overall assessment of population change in the eastern region. The results of these inquiries have been reported elsewhere (Unesco/UNFPA 1977; Bedford 1978a; Bedford and Brookfield 1979).

The subject of this section is therefore internal migration, and the discussion falls into four relatively discrete parts. The first contains a review of certain fundamental conceptual and methodological issues which must be considered when dealing with the process of population movement. A summary of the main findings of the Fiji mobility inquiries follows and provides a background to examination of selected explanatory generalizations which have been proposed to account for different types of population movement in the Third World. In a short concluding discussion some consequences of rural depopulation for social and economic development in small island peripheries are outlined. Themes of relevance in the context of planning for demographic change are suggested here, and these are explored at greater length in the final contribution of this Technical Note.

### Table 1: Island populations, areas and densities, eastern Fiji, 1976

<table>
<thead>
<tr>
<th>Population</th>
<th>Islands</th>
<th>Area (km²)</th>
<th>Islands</th>
<th>Density (People/km²)</th>
<th>Islands</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-99</td>
<td>6</td>
<td>15.0</td>
<td>17</td>
<td>42.5</td>
<td>13</td>
</tr>
<tr>
<td>100-99</td>
<td>14</td>
<td>10.5</td>
<td>13</td>
<td>32.5</td>
<td>15</td>
</tr>
<tr>
<td>100-99</td>
<td>12</td>
<td>30.0</td>
<td>9</td>
<td>40.9</td>
<td>8</td>
</tr>
<tr>
<td>100+</td>
<td>9</td>
<td>22.5</td>
<td>100+</td>
<td>4.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>


**Introduction**

Compared with fertility and mortality, population movement is a very difficult process to define in a manner which has uniform meaning and relevance to the range of spatial, temporal and cultural contexts. There is a high degree of consistency in the statistical sources of vital rates and deaths in different populations, places and periods. In the case of population movement, however, the only unambiguous element in the numerous statements about this process is that in order to have 'a move' there must be some spatial relocation. Conceptual confusion arises because, as Goldschneider (1971) has pointed out, there is neither a biological referent for nor any inherent uniformity in population movement.

Inevitably the first critical issue which has to be resolved by those concerned with the measurement and analysis of population movement is one of definition. Questions of 'definition' and 'type' are rarely relevant when dealing with reproduction and death. But in the case of mobility several important questions arise, such as what sorts of relocations to include within the broad concept of 'migration', how to delimit 'movements from elsewhere', what types of movements to investigate. In resolving these questions Goldstein's (1976, p. 428) recent caution is well worth bearing in mind: We must avoid reliance on outdated and inappropriate concepts, questions and measures, those whose sacredness stems only from the fact that they have been used in the past and most often in the developed world.

**The Domain of Internal Migration**

The MB 7 pilot project in eastern Fiji was concerned primarily with movements of people within a nation's boundaries. When collecting information on the diversity of mobility experiences of individuals and families, details of trips outside Fiji were recorded, but the intent was to provide only a very small part of Fijian population movement. The main focus of inquiry was therefore that subset of spatial mobility which is usually subsumed under the label of 'internal migration'.

There is no generally accepted definition of 'a move' in the vast literature on internal migration. In most studies some distinction is drawn between 'temporary' and 'permanent' movements. A continuum in mobility is implied - and sometimes explicitly stated - extending from the shortest, most repetitive movements associated with daily living, to long-term changes in place of residence involving a shift to a distant part of the country. The nature of those moves termed 'migrations' on the continuum varies considerably, but usually it is assumed that this form of spatial mobility involves individuals, families or groups in the absence of connections representing adjustments to one habitat, and the establishment of a new set of bonds in a new location. Thus change in the international or 'normative' system of the migrants is seen to be an inevitable consequence of most long-term relocations. A notion frequently associated with migration is the intention to move 'permanently' to another place of residence. Migration, as defined above, is usually differentiated from the numerous forms of spatial mobility which involve temporary absence from a place considered to be 'home'. These temporary moves have been grouped under the heading of 'circulation' which Tilly's (1971, p. 225-6) defines as 'a great variety of movements, usually short-term, repetitive, or cyclic in nature. All are underlain by the common lack of any declared intention of permanent or long-lasting change of residence'.

In much of the demographic literature this circular mobility is excluded a priori from the research domain of internal migration.

**Migration and Boundaries**

In addition to the requirement that the moves under consideration represent long-term changes in place of residence, an additional definitional constraint is often imposed in the requirement that the move crosses some administrative boundary. Tomlinson (1965, p. 211), for example, has argued that order to be considered a migrant one must make a move of some consequence and place of normal habitation for a considerable period of time, crossing a political boundary in the process. An implicit assumption here is that by shifting into another administrative or political unit one may experience a considerable change in the lives of people, even if it is not apparent or environmental change from population movements within such units.

Considerations such as these recently led one writer to suggest that 'it would seem that
an area of at least 1000 square miles and a population of 2000 and is 'required for a meaningful analysis of internal migrant movement' (Roberts 1976, p. 43). In his review of some of the conceptual problems associated with the measurement of population movement in small countries, Roberts felt that because there are only short periods over which people may have to travel to reach towns or move into different administrative areas, it becomes very difficult to distinguish between local movement and 'genuine internal migration'. This argument is not an unusual one; Donald Bogue (1959, p. 489) has suggested that 'theoretically the term 'migration' is reserved for those changes of residence that involve a complete change and readjustment of the community affiliations of the individual'.

In recent years such definitions of the relevant domain for the concept of internal migration have strongly been challenged. The arbitrary nature of administrative units and the unwarranted assumption that change, both for the individual and the society at large, must be at a minimum when movement takes place within each unit, seriously detracts from the utility of boundary crossing as a tool for distinguishing analytically between types of mobility within countries. In a similar way, attempts to justify limiting the universe of internal migration to those moves which involve a 'complete change and readjustment of the community affiliations of the individual' is, as Goldscheider (1971, p. 62) argued, 'unnecessarily restrictive, unjustifiable theoretically, and unworkable empirically'. Voluntary movement of any kind rarely leads to total severance of connections to people, events and places in a former residential environment.

Problems with permanence

In some social and cultural contexts the notion of 'permanency' relocation has very limited relevance for the study of population movement. In the island countries of the South Pacific, for example, the label 'home' is invariably ascribed to that place (or places) where the individual's family lived before he or she left to land. As a Fijian stressed at a recent conference on population movement, she will always regard the place where her father was born as 'home' even though she has lived there for less than one of her thirty-three years - 'home' including the homes of our relatives in Fiji, on our land. This represents security and something permanent. It represents our roots' (Racule 1978, p. 41).

In New Guinea two approaches are commonly adopted to assess the degree of permanence of a residential shift. The first is based on a subjective evaluation of the 'intentions' of the mover - the extent to which he sees himself as leaving or staying away for a limited time, as 'for good'. The main problem with this approach is that in spite of stated intentions to the contrary the new home, in fact, stays only a short time at the destination before returning to the place where he was previously in residence. Similarly, a self-styled 'temporary' mover may end up staying at the destination and never going back 'home' as intended.

The other approach involves establishing some critical duration of residence at the destination. In this case the criterion for defining migrants from transient sojourners is an objective one - an externally imposed arbitrary length of time at the destination. A requirement for qualifying as 'a migrant' is often used in national censuses is at least one year in residence at a new address. However, there is no general agreement on this matter and, as Mangalam and Morgan (1968, p. 8) point out, 'the period of time implied by the term permanency cannot be generalized in all instances of migration, but has to be considered individually in each case'.

A focus on the nature of activity systems, social fields and contact networks is useful when endeavoring to keep track of two closely related migration movements and population redistribution. Obviously all movement leads to a redistribution of population but as Gould and the individual's round of activities is substantially restructured in another location. This has been shown in some sociological and ethnographic work by studying the processes whereby foreign workers move into town. Mitchell (1969a, 1969b), for example, was not so concerned about the intended duration of moves and the location of a place called 'home' in his analyses of African population movement and urbanization. More important criteria were the extent to which longer periods were being spent in continuous residence in town, and the nature of involvement in acts of social relationships at the destination which tended to counterbalance, but not necessarily replace, those the migrant had in other places.

Where is the base?

If the individual's round of activities is substantially restructured in another location, this means determining for individual migrants whether their dominant pattern of movement, circulation, is from a base in the country or from a base in town. Information on activity systems and social mobility attachments are required to make this kind of distinction.

Approach adopted in the Fiji study

Each of the recent literature dealing with population change in the western Pacific (Melanesia) is based on a number of problems associated with rapid urbanization. National censuses suggest that a significant redistribution of population is taking place in most Melanesian countries where numbers in towns are estimated to be growing annually at a rate of 5 to 10 per annum. Cross-sectional information on population movement which can be obtained from the census implies that much of this growth is due to net in-migration from rural areas. However, there is abundant evidence in more detailed data of social mobility to suggest that this onward drift differs significantly from the classic pattern of rural-urban migration in the western Pacific has not yet led to the creation of a sizeable new urban working population which has severed ties with former rural 'homes'.

The rural-urban drift revealed in Melanesian censuses is part of a more complex mobility process in which relocations of individuals and families are often only temporary. In addition to suggesting that a redistribution of population is taking place, recent increases in levels of urbanization also reflect growth in the circulation of villagers into, out of and through towns. This circular mobility cannot be readily identified in the existing census data in Melanesia, but such movement is highlighted when a longitudinal approach to data collection is adopted.

One month as an arbitrary limit

If Fiji the decision was made to concentrate on population movement and spatial mobility which satisfied the constraints that a move resulted in a change in place of residence at least one month. The arbitrary limit of one month in residence at the destination was chosen partly on conceptual grounds and partly for methodological reasons. It was felt that most Fijians who move to another location for a month or more have to restructure their round of activities quite substantially in order to ensure a satisfactory livelihood at the destination. Obviously there will be exceptions and other temporal limits could have been adopted to identify a relevant mobility universe. However, it was here that the particular methodology adopted in this study proved a constraint. Retrospective mobility histories (discussed further below) could have been used to identify mobility, but it was quickly found to be impractical to expect people to recall past moves which had taken place to other places for only a few days or one or two weeks.

It must be acknowledged that this decision to use this period of one month as the unit of registration had the effect of excluding numerous forms of circulation from inquiry. Short-term social
visits, hunting and fishing trips, participation in ceremonial activities in neighbouring communities, the cultivation of gardens and the journey to work, visits to hospitals and schools. As a result, they lay outside the concept of internal migration as defined in the Fiji study. However, most of this very short-range movement involves the voter shifting social-structural attachments and the locus of his activity system to another location. If these shifting milieux are involved, it can be argued that these sorts of moves can be excluded from a concept of 'internal migration' on both qualitative and analytical grounds.

COLLECTING INFORMATION ON INTERNAL MIGRATION

Census data and their limitations

For a number of years now the collection of information on population movement has been an integral part of national censuses in Pacific countries. One or two questions have been inserted in census schedules to derive measures of the magnitude of flows between specified areas - administrative units (faisali; occasionally, local communities. Until recently, the time period over which the population movement information is collected in official censuses occurred could not be determined - the statistics related simply to numbers enumerated in each area by area of birth or the place where customary rights to land guaranteed residence rights (the 'home' province/ island/community). There was no way of establishing how much of the movement between natal or 'home' place and place of enumeration was recent or long-standing or how long an individual permanently remained. The spatial matrix for these crude flows was also highly generalized in some countries. In Fiji, for example, national censuses since the mid-1950s, for example, data on internal migration are only available for moves between the 14 administrative provinces which encompass over 100 inhabited islands.

During the 1970s additional reference points were included in censuses to generate more precise data on internal migration. Questions on place of usual residence at a previous census, at the time of an important local event (such as national independence), or at a time specified (usually one week or two weeks) before the enumeration have been used in the latest round of censuses in the region. While more precise temporal domains can be established for movement flows between provinces, islands/community, there is no reason to believe that the actual data tend to create a rather false impression of order and direction in what is a highly dynamic situation. In other words, it is believed that much of the residential mobility is of a temporary or short-term nature, longitudinal approaches must be employed to assess the essential characteristics and consequences of population movement. In concluding the discussion of the section of this chapter on the measurement of internal migration, it is noted that measures of internal migration can be obtained by asking individuals (by survey) when undertaking and analysing internal migration, an outline is given of two methods of obtaining data on movement through time in societies where there is no tradition of written records.

Retrospective movement histories

A method commonly employed to collect information on mobility during intensive field inquiries is the compilation of movement histories. Respondents are asked to recall moves involving a specified period in residence. Questions eliciting information about the timing and motives for previous moves are directed towards reconstructing situations in the respondent's past. From these data the pattern of movements (e.g. stepwise, circular) can be established as well as post facto rationalizations of reasons for the moves.

There are two very obvious limitations to this technical of data collection. In the first place there is a strong possibility that some moves will not be recalled. This will be a major problem where some arbitrary definition of a move is adopted which has little meaning in the context of local social and economic behaviour. When selecting a minimum definition for movement, it should be borne in mind that measurement of time can be conducted from a number of different and often unrelated standpoints in different societies. Three 'standards' of measurement have been suggested in societies, such as those in the south Pacific, where there is no tradition of writing:

- one based on ecological occurrences (climatic and plane cycles, animal behaviour);
- one based on recurrent events in the social system (initiation and grading ceremonies, marketing and trading, inter-group relations);
- one based on periods divided by, say, village organizations or group migrations (Vanuata 1965).

Ecological time is essentially cyclical and seldom spans periods exceeding a year or an agricultural season. Sociological time may extend over some generations into the past and also tends to be cyclical, relating to the life-cycle events of individuals. Time measured in terms of major events in local history will vary considerably in temporal depth.

The three ways of measuring time can coexist within the same society, and there is generally a lack of co-ordination between the two approaches. Consequently, definitions of moves as shifts involving residence in another place for say six months, two years or five years may have little meaning to respondents in societies without a tradition of measuring time on the basis of a 12 month calendar. Unless a temporal definition of a move relevant in the local context is used, there is a high probability that only partial movement histories will be obtained.

The problem of rationalization

The second problem with the movement history method relates to attempts to obtain an assessment of motives for past relocations. Past facto rationalizations will dominate responses to questions such as 'Why did you leave your last place of residence?'. 'I was born here'. 'Why did you move to this place?'. As a number of researchers have found, motives given by individuals in the past may hide, rather than reveal, underlying causes for movement. Not only do memories get highly diluted and some dramatic event may stand out in a migrant's narrative, rather than the cumulative effect of a series of moves, which are probably the real causes pushing a man to leave one place for another (Richards 1958). In some cases it is possible to assume motives on the basis of the type of destination and activity pursued there. This is easy enough when the activity is further education or the receipt of medical treatment. However, it does not assist us when the mover takes up wage employment in town or on some plantation. The reason which is given for moving to the latter places is invariably 'to obtain more money.' But this rationalization, solely in terms of economic motive, is unlikely to represent the whole truth for a considerable number of past migrations.

The whole life history approach

Given these methodological problems is to adopt a whole life history approach. In this way information is obtained on education, marriage, family and occupational histories as well as on previous moves. Emphasis on sequence and temporal congruity reduces the probability of respondents failing to recall particular moves (Daly 1974). In addition, the additional information it is easier to put the movements into correct sequence and to date them more precisely than the individual's life span. From information on population movement collected in life histories it is often found that the balance of economic, political, social and personal factors favouring the decision to move varies consistently with a person's stage in the life cycle. This is hardly a revolutionary discovery, but the important point to note is that the factors of movement mobility at different times in a person's life have been specified by the respondents, and not inferred by the researcher.

Retrospective movement histories clearly demonstrate that the common division of a population at a point in time, such as a census night, into 'migrants' and 'non-migrants' on the basis of presence or absence from specified locations is rather meaningless in Melanesia. An examination of the movement histories of over 500 adult New Hebrides, for example, shows that these enumerated in rural communities had been just as mobile as their kin temporarily resident in the towns of Port Vila.

The de facto censuses carried out in the villages and urban settlements merely truncated these highly complex mobility patterns. Movements involving variable periods of residence in a wide range of locations amounted to this being part of the lifestyle of people from all communities studied.

Current mobility registers

The peripatetic behaviour of Pacific Islanders has become even more apparent since moves of a certain duration in and out of particular localities are actually recorded over a reasonably lengthy period. Conceptually this is a much more satisfactory method of collecting data on mobility in non-literacy societies than collection of retrospective movement histories. However, the maintenance of a current movement register usually requires that the researcher spend long periods in residence in selected communities. In a pioneering study, Chapman (1970; 1974), established and maintained registers of movements in and out of two villages in the Solomon Islands over a ten month period. The definition of a move used in this study was an absence from
III. POPULATION MOVEMENT IN EASTERN FIJI: A DESCRIPTIVE OVERVIEW

The inquiry into mobility in the eastern islands was framed with the knowledge that a major redistribution of the Fijian population had been in progress for some time. A central concern was to establish reasons for accelerating net out-migration so as to understand a trend towards absolute population decline in islands which could support far more people at present levels of living or alternatively could support higher production and thus higher incomes for the present residents. Heavy emigration was seen as evidence of widespread dissatisfaction with village life, an important consideration in the context of carrying capacity in small island ecosystems. During early stages of the Fijian project, it was argued that 'whatever may be the theoretical levels of carrying capacity, the perceived or realized carrying capacity must be assumed to be declining where there is increasing out-migration'.

To gain a better understanding of the role of population movement as a regulator of demographic as well as social and economic development, inquiries were carried out at three scales - the region, the island, and the community. Some of the main findings have been abstracted from the project's various reports and are summarized below. A number of tables serve to place the project's population domain in perspective for those readers unfamiliar with Fiji and its eastern islands. Explanation of trends identified in this descriptive overview is the subject of the next section.

THE DRIFT TO TOWNS

Since the mid 1950s, Fiji's decennial censuses have indicated that the populations of many small islands have been growing at much slower rates than the national average. In 1956 the 40 inhabited islands in the provinces of Lau and Lomaviti and the Tavuani administrative district contained 38 per cent of the nation's Fijians. The Indo-Fijian component of the region's population has always been small, and is not included in the following discussion. By 1976 the proportion of Fijians who were living in the eastern islands had fallen to 13 per cent (Table 2). Over

the last intercensal period (1966 to 1976) the divergence between national and regional growth trends became particularly marked.

The main destinations for those who left western Fiji were, and remain, towns on Viti Levu and Vamous Levu. Between 1966 and 1976 the Fijian population enumerated in urban areas rose by 65 per cent; in Suva the increase was 83 per cent (Table 2). Boundary changes since the 1966 enumeration are responsible for some of this increase, but a major demographic development in Fiji since the mid-1960s has been the drift of Fijians to towns, especially the capital Suva. Some indication of the magnitude of this movement can be obtained from census figures for the two provinces in eastern Fiji - Lau and Lomaviti. Unfortunately statistics at the district level are not available and recent trends in the redistribution of population in Tavuani district can only be estimated.

Movement from eastern Fiji: a macro-view

In the 1976 census two questions generated information which could be used to assess aspects of population movement. The first concerned place of birth and the second place of usual residence in 1970, the year Fiji
gained independence. These reference points have been cross-classified at the provincial level with province of enumeration for the different ethnic groups. A summary of the relevant data for Fijians born in, or resident at the time of independence in, Lau and Lomalavi Provinces is given in Table 3. Of the 39,000 born in the two provinces slightly more than half were enumerated there in 1976; if the adults (15 years and over) are considered separately, only 44 per cent were resident in their provinces of birth. Lau Province had lost a greater proportion of its natal population than Lomalavi, but the statistics on more recent relocation would suggest that rates of movement away from both areas are now fairly even. In the six years before the census, for example, a quarter of the Fijians in Lau and 24 per cent of those in Lomalavi in 1976 moved to another province (Table 3).

As mentioned above, the main destinations for these eastern islanders have been provinces containing Fiji-born towns. Over 60 per cent of the Lau- and Lomalavi-born absences as well as those who moved in the six years before the census, were resident in 'urban' provinces in 1976. Obviously not all these migrants were living in towns, but the much higher rates of growth for urban areas than the rural-resident population would suggest that the balance of change to towns rather than inter-rural relocation is the most important macro-dimension of internal migration in Fiji to date. In 1976, 54 per cent of Lomalavi who were living outside their provinces of birth were enumerated in Suva. Whereas these two provinces contained 19 per cent of the country's Fijians in 1976, 20 per cent of this ethnic group in the capital city were Lauans or from Lomalavi.

So far attention has been focused on movement away from the eastern islands - what of the counter-streams? The populations of Lau and Lomalavi in 1976 included Fijians born in all of the nation's provinces. However, these flows into the small islands replaced only a fraction of the emigrants - whereas over 16,000 had left, only 4,000 Fijians born in other provinces were enumerated in Lau and Lomalavi. A quarter of these immigrants had come from other parts of the eastern region.

**Actual and projected populations**

To get a clearer indication of the magnitude and demographic character of net migration, a technique for projecting the Fijian population forward by age group and sex using survival ratios obtained from model life tables was applied to the census data for 1966. Expected populations, assuming no migration, were compared with the enumerated groups in 1976 to derive estimates of losses to populations in different parts of the region. There are a number of limitations associated with application of this technique in eastern Fiji, and these have been discussed in the project's first general report (Enoasco/UFPA 1977, p. 137). It is sufficient to note here that the recent availability of age-sex data for provinces in 1976 has removed one of the problems mentioned in the earlier report, although the net migration estimates given in the nature of the assumptions made about mortality rates.

Over the decade eastern Fiji lost the equivalent of more than a quarter of its 1966 residents through net out-migration (Table 6). Losses were heaviest in Lau Province (32 per cent) and lowest in Tavua District (19 per cent) - the area with the largest and most diverse island economy and society in the region studied by the project. While variations in the magnitude of net migration are of interest, a more important characteristic of the flows summarized in Table 4 is their age-sex composition. The proportion of children and women were much higher than expected given the hypothesis that movement was predominantly of a circular nature. Family or household relocation has been very common in recent years and this suggests long-term rather than temporary movement from the region.

**Residence of Landowners**

Another perspective on population losses, which can be established by data collected in the project at island and community levels, relates to the residence of landowners. The Native Lands Trust Board maintains registers of all Fijian who have customary rights in the primary land-owning units, the mataqali. Even though these registers are known to be incomplete, the names of many Fijian children born and resident in town are not included, they do provide a further indication of the extent to which, if free populations in the eastern region are only a fraction of the numbers which actually have rights to land. On Kahara in southern Lau, for example, less than one third of the registered landowners were in residence at the time of a project census in October 1975. An even smaller proportion were living on Batiki in Lomalavi Province when a government-sponsored survey was carried out in 1974 - only 23 per cent of those listed in the relevant mataqali registers were present (Bayliss-Smith 1977).

It will be appreciated that these registers include the names of people who have never lived in the areas where they have rights to land and who, therefore, cannot be clasmic as migrants. However, the sort of information yielded by this source highlights a very important aspect of the region's socio-economic development in recent years - the flight from the land. At the time of the 1956 census it was found that of all Fijians claiming land in Lau and Lomalavi, 83 per cent and 70 per cent respectively were living in the two provinces. Similar information was not collected in the 1966 and 1976 censuses but, if the Batiki and Kahara cases cited above are any guide, it would seem that less than half those claiming rights to land in the two provinces would have been in residence by the mid-1970s.

**Residence in town**

When reviewing trends in Fijian population

<table>
<thead>
<tr>
<th>POPULATION</th>
<th>PROVINCE</th>
<th>LAU</th>
<th>LOMALAVI</th>
<th>TOTAL</th>
<th>TWO PROVINCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Born in provinces</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total enumerated in Fij</td>
<td>25,999</td>
<td>15,442</td>
<td>41,441</td>
<td>39,041</td>
<td></td>
</tr>
<tr>
<td>1 in province</td>
<td>53.2</td>
<td>56.7</td>
<td>56.4</td>
<td>56.7</td>
<td></td>
</tr>
<tr>
<td>2 adults in province</td>
<td>41.4</td>
<td>44.4</td>
<td>44.4</td>
<td>44.4</td>
<td></td>
</tr>
<tr>
<td>Number absent from province</td>
<td>10,978</td>
<td>5,833</td>
<td>16,811</td>
<td>8,393</td>
<td></td>
</tr>
<tr>
<td>1 in 'urban' provinces*</td>
<td>83.0</td>
<td>83.9</td>
<td>83.9</td>
<td>83.9</td>
<td></td>
</tr>
<tr>
<td>1 in Suva</td>
<td>57.1</td>
<td>51.1</td>
<td>55.0</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td>Resident in town</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number in province</td>
<td>14,056</td>
<td>11,173</td>
<td>25,229</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 in town</td>
<td>75.9</td>
<td>75.1</td>
<td>75.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number left since 1970</td>
<td>3,590</td>
<td>2,683</td>
<td>6,273</td>
<td>84.0</td>
<td></td>
</tr>
</tbody>
</table>
movement in the late 1950s, Ward (1961, p. 265) commented:

For the first time, it has been regarded as almost traditional for young Fijian men to leave home, to go to the gold mines or some other employment centre for a period of a few months to one or two years, and then return to their villages. ... This type of employment, however, has become less and less typical. As the contrast between urban and rural living has increased (particularly in the postwar era), and as the number of Fijians in the towns has grown (thus making it easier for the newcomer to find friends), the migrant’s desire to return home has grown progressively less. ... Once a family, or part of a family, is established in Suva or some other urban centre they frequently find themselves supporting kinsfolk who have followed them to town. Many of these are school children sent in by parents unable or unwilling to move themselves yet anxious to have their children educated in the city. Another section of this secondary wave of migrants consists of elderly people whose younger kinfolk on whom they must depend in their old age have migrated earlier. ... The second wave of elderly migrants consists of the problem of the elder woman in Suva’s crowded housing conditions in the town. It also marks a further step in the break from the land and family kin on which Ward’s argument that the pattern of short-duration circular mobility from a base in the rural area to Suva for a young man’s long-term residence in urban areas was common had the support of an eminent Fijian sociologist, Y. N. G. Dhibani. Over a decade ago, Nayingaklu (1963, p. 34) stressed that: ‘There is little doubt that the great majority of the young Fijian males destined to be permanently settled in the urban centres are destined to be permanently satisfied there’. Evidence from various studies during the 1970s and 1980s shows that students from the University of the South Pacific in Suva highlights this trend towards stabilisation of urban residence amongst migrant Fijians. Examples may be found in the work of Walsh (1976; 1977) Ralce (1974) and Darce (1973).

A survey in Qaua, outside Suva

To get some perspective on the recent movement behaviour of an urban-based component of Fijians from Lau Province, a sample survey was conducted as a part of a project in the migrant settlement of Qaua near Suva. Of 81 persons in residence in January 1976 who had been born on a Lau island, over 40 per cent had spent most of their lives in town. Those aged over 25 years had been just as ‘stable’ in urban residence as their younger kin. ... Indeed, over 70 per cent of the Fijian men had arrived in Suva before 1965. Almost 80 per cent of the sample had lived in Qaua in 1971 and the same number had moved into this treatment, selling handicrafts or roots, perhaps purchasing supplies, or calling on friends. A number of short visits often turns out to be a much longer stay than intended, especially for unmarried men. Many of the older family commitments to call them home. Over time the net migration loss of younger, more dynamic members of small island populations continues as numbers in urban settlements grow at the expense of the villages.

A RURAL PERSPECTIVE

An inquiry into the movement behaviour of villagers will inevitably produce rather different perspectives on the pattern and process of internal migration from one focussed on the behaviour of urban residents. Research in rural Melanesia tends to highlight the circular nature of much contemporary population movements, and it is emphasised that rural residents still exist on the island as a result of cultural and economic factors. The islander is often influenced by the manifold dimensions of internal migration in countries where the essential ‘cultural focus’ of the indigenous society still rests on status as land owners rather than as members of a wage-earning proletariat. The situation is even more complex in rural as well as urban viewpoints, even if the overall impression one gets from the statistics is in increasing, the copulation drift to the cities.

In Fiji intensive field inquiry into mobility was carried out with local communities. This is hardly surprising, given the people’s focus on the ecological, socio-economic and demographic characteristics of small islands. A rural bias in the field research did not, however, obscure the fundamental population redistribution which has been taking place for some decades. Circular movement from a rural base was found to dominate mobility histories of villages and, whilst both de facto and de jure enumerations drew attention to the fact that the numbers operating from such a base are dwindling rapidly, especially on the very small islands. A view from Lomaloli

Village populations are in a constant state of flux. When examining changes in the composition of Lomaloli’s population, for example, Bayliss-Smith (1977, p. 86-90) found that between the years 1971 and 1978, the number of resident non-Fijian peoples of normal age group (20-65) and foreign born or introduced by marriage, in the villages of Nacamat passed from a total of 238 to 277. However, the total number of Lomaloli-born and Lomaloli-related persons who had spent some time on the islands was 338 in 1971 and 347 in 1978. Thus it can be seen that the total number of migrants to the island has been relatively small, comprised all those born on, or related to people born on Lomaloli, who had spent some time in the four villages over the years before and after 1975. The de jure population totalled 338 and the great majority of adults (66 per cent) had made one or more moves to and from the island since 1973. Examination of the recent mobility experiences of a similar de jure population for Nacamat village on the larger island of Koro revealed much the same basic pattern (Bayliss-Smith 1977, p. 29-31). Circulation between village and other rural as well as urban communities is the island in now part of the life-style of all except the very young. It barely if possible to directly assess the degree to which circulation of population is a feature of any one village or area. In fact, mobility has intensified over time. For Nacamat village Bayliss-Smith was fortunate enough to have data on inter-village movement experiences for all residents as long ago as 1973. In his study of this village in the late 1950s and early 1960s, Bruce (1969, p. 41) found that 34 per cent of the 344 residents had never travelled outside Koro Island. Sixteen years later Bayliss-Smith found that 75 per cent had been to other islands and a lack of travel experience was confined almost entirely to the very young of age. The presence of large numbers of Fijian people living elsewhere in Fiji on a fairly permanent basis today is encouraging the extensive travelling of Nacamat villagers to other islands.

The desire to maintain contact with widely dispersed kinsfolk who ‘belong’ to a particular place in the sense of having customary rights to land there, is reflected in the reasons given by the population for their outward journeys between 1973 and 1975. Holidays—often quite prolonged—were often taken in Suva or Levuka (a small town in Lomaloli) and Lomaloli emerged as the most important reason for marriage among the Lomaloli population (Table 5). Movements associated with employment were more common to one or,
in the case of 36 men employed on two commercial fishing boats operating out of Batiki, to pursue a particular occupation) came next in the hierarchy of reasons, followed closely by the outward trips of teenagers to secondary schools.

Considering how different the two islands are in size, resource endowment, self-sufficiency and prosperity, Batiki was surmised to be a striking anomaly in the patterns of mobility of Koro's Nacanaki residents and the Batiki villagers. Be commented: 'These two Lomavitis Islands have very similar requirements for contact with the outside world' (Bayliss-Smith, 1978, p. 90). This is a valid conclusion on the basis of stated reasons for recent mobility but one must not lose sight of a major difference in the net effect of mobility in the longer term course of population change on the two islands. Batiki's resident population declined by 13 per cent between 1966 and 1976. Over the same period, numbers on Koro rose by 13 per cent.

Batiki, like many of the very small islands in Lau Province and to the north of Taveuni, has lost a much higher proportion of its population with land rights to long term residence in other parts of the country than is the case on larger islands. As Bayliss-Smith points out, only 30 per cent of 1200 people who might have spent some time on Batiki between 1975 and 1975 were in the villages during the two years. The vast majority (70 per cent) never visited the island. Although the sort of information required for this analysis is not available for Koro, it is believed unlikely that such a large proportion of the Pijians with rights to property on the island were without direct

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**Table 1:** Reasons for movement from Batiki and Nacanaki, 1975-76

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage of outward trips motivated by stated reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>37</td>
</tr>
<tr>
<td>Emigration</td>
<td>48</td>
</tr>
<tr>
<td>Schooling</td>
<td>23</td>
</tr>
<tr>
<td>Employment</td>
<td>13</td>
</tr>
<tr>
<td>Marriage</td>
<td>5</td>
</tr>
<tr>
<td>Relocation</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>100</td>
</tr>
</tbody>
</table>

**Data:** Bayliss-Smith (1978)

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**Table 2:** Movement experiences between 1975 and 1975 of household heads on Koro and four villages on Koro

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Household Heads KOROH</th>
<th>Household Heads QOLENI</th>
<th>KOROH</th>
<th>QOLENI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent 1-6 months more</td>
<td>36.0</td>
<td>81.2</td>
<td>43.6</td>
<td>43.6</td>
</tr>
<tr>
<td>than once</td>
<td>35.4</td>
<td>83.4</td>
<td>35.6</td>
<td>35.6</td>
</tr>
<tr>
<td>Worked in town</td>
<td>17.2</td>
<td>22.7</td>
<td>17.2</td>
<td>22.7</td>
</tr>
<tr>
<td>Worked in rural area</td>
<td>37.9</td>
<td>53.3</td>
<td>37.9</td>
<td>53.3</td>
</tr>
<tr>
<td>Worked in N. Fiji</td>
<td>45.2</td>
<td>53.3</td>
<td>45.2</td>
<td>53.3</td>
</tr>
<tr>
<td>Destined last movement</td>
<td>31.0</td>
<td>68.2</td>
<td>31.0</td>
<td>68.2</td>
</tr>
<tr>
<td>Works for wages</td>
<td>13.8</td>
<td>32.1</td>
<td>13.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Data: Bayliss-Smith (1978, p. 136)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Figure**

A longitudinal approach is taken to the collection of data on mobility. Movement histories for adult males in Qeleni Village and Koro revealed that considerable proportions had resided in other parts of Fiji for periods of a month or more during the five years before interview. In Qeleni, just over 40 per cent of those aged 15 years and over had made more than one move which involved residence at the destination for over a month since 1971. However, while almost half stated they had lived in a town for the requisite period, only 19 per cent actually had paid employment in urban areas. As in Lomaviti, the majority had been visiting relatives and friends. Rural wage employment had kept marginally more men (20 per cent) away from the village for at least a month at some stage over the five years, and plantations on Vanua Levu and neighbouring Leusela were the main destinations given. Even though some of the men had been quite mobile, the majority (84 per cent) claimed to have been in residence in Qeleni in 1971, and an even higher proportion (89 per cent) had spent more than three of the five years living in the village.

In terms of numbers of absences for periods of a month or more, and time in residence/employment in towns, Kabaran household heads gave evidence of more extensive mobility since 1971 (Table 6). A slightly higher proportion of the Qeleni males had rural employment away from its village, a finding which is hardly surprising given the proximity of estates offering jobs on Taveuni and nearby islands. While a much smaller proportion had been absent from Kabaran in the six months before the survey then in Qeleni, it was found that 48 per cent had been living elsewhere for a month or more between October 1974 and October 1975. The main destinations of and reasons for last absence were quite different. In the case of Qeleni's household heads, other parts of Taveuni and places on Vanua Levu accounted for 59 per cent of the stated destinations. On the other hand, Suva was the location specified by over two-thirds of those on Kabara (Table 6). Employment for wages was given as the objective of their last move by a very small proportion (14 per cent) of the Qeleni men; on Kabara 50 per cent stated they had left the island to earn money in towns.

It is hardly surprising that there are some major differences in the recent migration experiences of adult males living in a Taveuni village compared to those in Fiji. The latter have been battered by two severe hurricanes in successive years since 1973 (Campbell 1977). After the Lomaliki Village population was scattered by the same fluctuations in price which profoundly affected the copra industry throughout Fiji and reaped the benefits of declining cash returns from this crop have been more nearly as great as Kabaran. Coconut groves on Taveuni were not destroyed by the hurricanes in December 1973 (Lottie) and January 1975 (Yali) which effectively removed coconut oil and copra production activity on Kabara until the late 1970s.

Kaleri's farmers have also been able to shift labour inputs into production of root crops (taro and yamoids) in demand in urban markets and on the estates, but which cannot be cultivated in Kabaran's harsh environment. The alternative cash earning activity on the latter island is production of wooden handicrafts but demand for these was also severely depressed in the mid-1970s accompanying recession in the tourist industry. Locally generated cash incomes were very low during 1975 and Kabaran household heads were heavily dependent on wages earned outside the island. Indeed in October of that year heads of 10 of the 33 households in Hakeleya, the largest village on Kabara, were either employed or seeking work in Suva. In Qeleni only one
household head was absent in August 1975. A combination of natural disasters and adverse market forces largely explains differences in the 1966 household mobility and urban工作经验s of the adult males in Geleni village and on Kabara island.

A detailed comparison of individual movement patterns

There are also some important differences between Geleni and Kabara in terms of the nature of recent net out-migration. Using records held in the Fiji National Archives, it was possible to compare names of residents enumerated in project surveys with those present in the two areas nine years earlier. In both cases it was found that less than half (44 per cent) of the residents in 1966 were still living in the communities at the time of the 1975 surveys. While levels of net out-migration were similar, the demographic composition of the flows and the destinations of those who had left were quite different. As far as Geleni is concerned, the major loss through net out-migration was among males aged between 15 and 29 years. Over 60 per cent of the 'emigrants' had gone to work in Suva or to other communities on Taveuni and rural areas in neighboring islands. Many had visited the village at least once since leaving.

In the case of Kabara, over half the net loss to the island's population consisted of adult women and young children. While families rather than just a male member left. Most had moved to Suva and, on the basis of information given for 79 absentees, relatives of resident household heads, it would appear that return visits were very infrequent. Three quarters of the absentee relatives had left before 1966; just under half had never returned since leaving, and for a further 30 per cent no one could recall when they had last visited the island. In common with the situation described by Boyden-Bethall for Batiki, the majority of Kabara's du lave population were not exercising their right to use land on this small, relatively isolated lagoon.

Discussion

Retrospective movement histories compiled for village residents will reveal invariably that 'return migration rather than linear migration is the dominant kind of mobility' (Chapman and Proctor, 1977, p. 8). Inquiry into internal migration at a range of scales in eastern Fiji using a combination of cross-sectional as well as longitudinal methods clearly demonstrated that accompanying the intensification of circular forms of movement over the past century, there has also been a fundamental redistribution in population. Evidence from the rural and urban surveys carried out by the project supports the view of Ward (1971, p. 103) that it is wishful thinking to claim that urban dwellers will return to the villages in which they were born. This is not to argue that Fijians living in Suva have severed their connections with former places of residence, or that they feel 'permanently committed' to living in the particular suburban/squatter settlement in which they were accommodated. It is to recognize that many who have left the region to work or stay in Suva do not return to live 'permanently' in former rural homes. The basis for their 'vast range of temporary excursions' has shifted from village to town.

IV. EXPLAINING POPULATION MOVEMENT

Implicit in most studies of population movement is the idea that this is a non-random phenomenon which is subject to scientific explanation and ultimately may be forecast with a reasonable degree of accuracy. An important limitation of theoretical statements devised to explain and estimate population flows, however, is the necessity to consider social, spatial and temporal domains. In this regard, Ravenstein's (1885; 1889) 'laws' of migration (1864) and Rapoport and Rapoport's (1966) expansion of these have particular relevance in the historical circumstances associated with achievement of high levels of urbanization and in(colsedustrialization in western societies. Ogilvie's (1979) theory of rural-urban migration in sub-Saharan Africa is restricted by its vety title to a particular spatial domain and, together with Mitchell's (1969a) conceptualization of circular migration, is constrained to a specific societal context. Habegger's (1970) theory of rural-urban migration has greater generality but, like Todaro's (1969) model of labor migration and urban unemployment, is limited in domain to a particular form of population movement. In a brief review of the current status of migration theory, Abur-Lughod (1975) has pointed out that re-assuringly simple explanations of mobility provided by the mathematical 'gravity' model or the 'push-pull' model on the economic level, and the psychic cost 'adaptation' model on the socio-psychological level have proved to be much more time-, place- and culture-specific than was ever anticipated. Acknowledgement of the inappropriateness of such assumptions has not yet had the effect of clarifying migration theory. As Abur-Lughod (1975, p. 212) says: 'In place of the satisfying closures offered by previous theories we find a tenuous morase of only dimly charted and far too complex terrain. The general "lay of the land" seems to be lost'.

Project research on population movement in eastern Fiji did not generate any new 'theories'. The information collected on aspects of living conditions in a range of rural environments, and the responses of different groups in village populations to accelerating changes in the structure of economy and society at national, regional and local levels, confirm a number of hypotheses which have been used to explain recent trends in population movement in other less developed countries. There is nonetheless a need to develop a more comprehensiveness on contemporary Pijam mobility, and the patterns and processes briefly summarized in the preceding section are being expanded into more general frameworks. In the following discussion, explanation of population movement is in two contexts: from the point of view of the 'necessary' conditions favouring aggregate flows of population from rural to urban areas, and with reference to a strategy of risk minimization which peasant producers operating on the margins of the commercial system adopt in the face of economic adversity. The end-product of this discussion is not another 'exploratory' model of either aggregate or specific pattern of decision-making process which results in some people moving while others remain in fms. Rather, the aim is to develop the idea that in the case that which has something in common with other mobility situations described for the western Pacific and developing agrarian societies in general. This is done in the belief that there is some hope for Abur-Lughod's (1975) claim that 'the findings from individual studies can yield cumulatively meaningful results', even if differences rather than similarities have come to be expected in studies of population movement.

'DETERMINANTS OF POPULATION MOVEMENT: A MACRO-VIEW

The economists' argument that the major determinant of population movement is an awareness of spatial imbalances in the distribution of economic opportunity and that rational desire on the part of individuals and households to maximize their incomes, is embodied in a number of pervasive theoretical constructs as well as a very extensive literature reporting the results of empirical inquiry. Internal migration is viewed in this context as a response to changing economic opportunity whereby the spatial allocation of labour is redirected towards a more optimal pattern. The notion that aggregate flows of population act as an equilibrating mechanism in a changing economy is implicit, if not explicit, in most migration studies. Measures of spatial disparities in per capita incomes, rates of unemployment, occupational and educational status of the labour force, degree of urbanization and other 'economic' dimensions of places and people are significant variables in models seeking to explain both volume and directional regularities in movement.

The assumption of rationality, as the economists narrowly define the term in the context of micro-economics, has proved inadequate as the foundation for a widely-based theory of population movement. Skill superiorities, human capital, social development advances have been made in the conceptualization and measurement of one of the most important components of migration in less developed countries - the drift of population from rural localities to urban areas in spite of growing levels of unemployment in towns. In the following discussion attention is focussed on the role of widening disparities in incomes and perceived opportunity between rural and urban areas in the internal migration process. The current 'revised' theory of 'rural-urban migration in less developed countries' (Abur-Lughod, 1971; 1976a) hypothesis - is outlined and examined briefly in the context of recent trends in aggregate population flows in eastern Fiji.

The Todaro formulation: a comment

As Garnaut et al. (1977, p. 9) have pointed out in their analysis of aggregate patterns of population movement to towns in Papua New Guinea...

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Demographic processes in small islands

In spite of its limitations as a theoretical framework for examining circular migration, the expected income hypothesis does offer a 'useful starting point' in the analysis of what Mitchell (1959; 1969a) calls the necessary conditions for labour migration - situations which are important in explaining the causes of movement from rural to urban areas. Mitchell argues that the necessary conditions for rural-to-urban drift are factors that change at a particular time. Economic factors such as the price of population on land resources, income disparities between rural and urban areas, rates of job creation and unemployment in town, prices for cash crops, the changing educational status of the labour force, are important necessary conditions for the circular urban-rural drift in less developed countries today, but they are obviously not sufficient conditions to explain urban and rural trends. Through the analysis of emotional and psychological factors involved in the process of circular migration, in particular the role of social and socio-political factors in Nias, the author has sought to explain the observed circular migration by providing a theoretical framework for examining circular migration in small island communities.

R.D. Bedford

Guineas: It is only recently that the conceptual apparatus has been developed in economics and social science to explain the existence of opportunities for additional productive employment in rural areas which do not employ amongst migrants in the town.

This theoretical development has evolved from a model proposed by Todaro (1969, p. 139) that the decision to migrate from villages to towns is functionally related to two primary factors: the urban-rural income differential and the probability of obtaining wage employment in the town.

Todaro (1967b, p. 30) has argued that individuals are assumed to base their decision to migrate on considerations of income maximization and what they perceive to be their expected income streams in rural and urban areas. It is further assumed that the individual who chooses to migrate is attempting to achieve the prevailing average income for his level of education or skill attainment in the urban centre of his choice. Nevertheless he is assumed to be aware of his limited chances of immediately securing wage employment and the likelihood that he will be unemployed or underemployed for a substantial period of time. The probability of being employed there rather than being underemployed in the traditional or 'informal' sector is very low.

This formulation has proved very attractive to most development economists because it provides a demonstration of the idea of being 'inevitably irrational: migration from rural areas, where a livelihood could be derived into towns which were perceived as having sufficient employment opportunities to cater for the existing urban population. The basic hypothesis retains an essential element of classical economic theory - income maximizing behaviour - by assuming that people weight the relative benefits of rural and urban labour employment over some lengthy period rather than simply on the basis of current real incomes. Thus, even if the probability of finding regular wage employment in the short-term is low and the expected income in this initial period is recognized as being lower than what could be obtained from rural employment, the decision to migrate is quite 'rational' as long as the migrant expects his probability of getting a job to increase over time, and for the value of his net stream of income in the longer period to exceed an anticipated rural income.

According to Todaro (1967b, p. 33) his probability function is formulated so that the longer the migrant has been in the city, the higher the probability of finding a job. While searching for regular work it is assumed that many new arrivals will generate some additional employment which will increase over time. Over time the migrants' contact networks and information systems expand so that their expectations increase about the chance of regular employment for new arrivals similar in age, sex, and skills.

Empirical data and the Todaro formulation

In the translation of theory and abstract mathematical formulation into statistical models which could be tested empirically using inadequate data bases in less developed countries, much of the conceptual elegance of the 'expected income' hypothesis had to be sacrificed. Todaro (1967b) himself has reviewed the relevant empirical work in economics, and points out that the most common approach to testing his hypothesis has been via least squares regression procedures to estimate macro-migration functions. Where measures of income disparity between the two areas where migrants have been included in the statistical analysis, the estimates are invariably among the most important explanatory variables. Some authors (e.g. Barron and Sabot 1976; Carvajal and Geltman 1974) have also demonstrated that the joint analysis of the independent and dependent variables in the regression procedures adds to the overall explanatory power of the regression equation and offers a more relative or absolute income differential.

Not all the findings from empirical tests are positive, however. Using extensive migration data from less developed countries, Connell et al (1976, p. 202) point out that contrary evidence in the impact of relative rural-urban income differentials or migration rates is due to inadequacies of the data on the source area's population in terms of unequal access to productive resources. Byresen (1975, p. 551) echoes this concern when he states:

The Todaro model which has been used to study the decision to migrate is quite 'rational' as long as the migrant expects his probability of getting a job to increase over time, and for the value of his net stream of income in the longer period to exceed an anticipated rural income.

In spite of its limitations as a theoretical framework for examining circular migration, the expected income hypothesis does offer a 'useful starting point' in the analysis of what Mitchell (1959; 1969a) calls the necessary conditions for labour migration - situations which are important in explaining the causes of movement from rural to urban areas. Mitchell argues that the necessary conditions for rural-to-urban drift in less developed countries today, but they are obviously not sufficient conditions to explain urban and rural trends. Through the analysis of emotional and psychological factors involved in the process of circular migration, in particular the role of social and socio-political factors in Nias, the author has sought to explain the observed circular migration by providing a theoretical framework for examining circular migration in small island communities.

R.D. Bedford
H. D. Bedford

Economic, political and social institutions: Our island world ceased to be. The world exploded and our islands became a remote outpost, the last place in a country which had surpassed us and much remaisness (Tabua 1969, p. 15).

Effect of entry into the market economy

The two necessary conditions for movement of population to towns were created by the process which converted diversified, integrated subsistence-based economies in small islands into disadvantaged units on the margins of a wider market economy. There are two dimensions to the shift from autonomy and self-sufficiency to deep dependence on external market forces and decision makers. The first was the spread of a uniform export crop economy which transformed highly specialized systems of resource exploitation on small islands and degraded a range of indigenous skills and practices. The project has described as the 'coucal overlay' has served residents in areas like eastern Fiji well at different times over the past century, but today it is the major reason for a depressed cash economy in most small islands.

Marked fluctuations in prices received by producers of copra have been and remain a significant source of dissatisfaction in the periphery. Not only has extensive planting of coconuts failed to generate the desired cash economy, but without the safety valve of emigration there would have been a serious land shortage problem. But shortage of land also motivates most of those who are living elsewhere to leave. Many with access to extensive tracts of land have been driven away by the land-hungry villagers. In this regard it is important to appreciate that in small island peripheries local resources have not been the sole source of livelihood for a considerable time. One of the benefits of integration into larger economic and political systems under colonialism has been an increase in the range of opportunities for satisfying needs in different places. Even in islands where productive land is not in short supply, the perceived returns from exploiting local resources have not been as attractive over time when compared with the benefits accruing from employment and residence elsewhere.

It has been demonstrated in an earlier work that if the inhabitants of islands in eastern Fiji had no option but to derive a livelihood within the island economy it is very likely (significant correlation 0.49) that there was in Fiji's urban households in 1972 (correlation coefficient 0.42).

With the financial rewards from coconut production proving so unreliable and small island producers suffering a number of what the minister for land and penalites (rising freight costs, rapid inflation in imported goods, deteriorating shipping services) it is hardly surprising that more younger Fijians in particular envisaged a more profitable future in the towns. Todaro's mathematical model of the rural-urban migration decision may not capture the 'thought process' of the Fijian migrant, but the logic of the model and the basic hypothesis that outlined earlier has relevance in the context of contemporary aggregate population flows from small islands to urban centers. Even though the rate of urban unemployment (percentage of the labour force without work and seeking it has been rising steadily since the mid 1960s, the perceived probability of obtaining a more satisfactory livelihood in town has remained high among eastern Fijians.

The social status dimension of migration

While widening income disparities between rural and urban areas coupled with a growing shortage of tenurial security has deepened spatial imbalance in distribution of those employment opportunities which more and more Fijians regard as more desirable for social as well as economic reasons. As in less developed countries, the differences between agricultural and non-agricultural employment in town have been widening. Although direct comparison is not easy because of the sizeable subsistence component in Melanesian village agriculture, some indication can be given of the rural-urban income disparity as it applied to part of eastern Fiji around the mid 1970s. In 1974 the average industrial worker in Suva earned around $31000 per annum (BNF 1974). On the basis of cash earning activities as well as an inputted monetary value for subsistence production, low-income rural households were found to have an income level at this time in 1975 (Bueno/UNPFA 1977; Bankoff 1978). By comparison with other parts of Fiji we were dealing with a relatively low-income population in the eastern islands - one which exhibited a considerable degree of inequality. Indeed, there was slightly greater inequality in village than urban incomes in 1975 (gender coefficient 0.469) than there was in Fiji's urban households in 1972 (gender coefficient 0.422).
leaving school. Sixty-seven per cent hoped to learn an industrial trade or enter a tertiary training centre of some kind; 67 per cent specified this was their chosen place of work; over three quarters gave 'the government' as the preferred employer (Bedford 1976a, p. 132). There is nothing surprising in these preferences; they would reflect occupational aspirations of secondary-education pupils throughout the country. A Fijiian summed up the present situation well when he commented:

And so we went to class rooms, grew up to put on ties and sweat in jackets, to pull white socks over our black skins. We looked around and took stock. We could tell those still with some way to go for they walked barefoot... We leave the old and infirm in the villages and rush to the towns. Some are employed, how lucky they are! Many more keep searching, looking for the jobs they may never find...

Their diploma of achievement is still open in capital letters - FRUSTRATION (Vuosaivatia 1978, p. 11).

As earlier emphasised, necessary conditions are not sufficient grounds for explaining why a particular individual chooses to move from a village to the city at a certain time. The decision to move from a village in eastern Fiji to a town on Viti Levu can be made for a host of reasons, not the least of which is the immediate desire to obtain urban employment. For at least a decade most residents in the small islands have at least one close relative living in town. In the detailed migration histories compiled for young male adults, visiting kin frequently figured as the main reason for departure from the village. A job in town may have followed, but the fact of migration to the city for at least the purposes of earning or saving money was a sufficient reason for leaving - the sufficient conditions for movement were not economic.

It cannot be denied, however, that a major relocation of population from small islands has accompanied a shift in favour of an urban rather than a rural base for obtaining a cash income and a socially desirable job. The most important necessary condition for the drift of Fijians from the eastern islands to towns in Viti Levu over the past 20 years has been change in occupational aspirations. Non-agricultural employment opportunities in the small island periphery are few and far between. Movement to Viti Levu has been necessary to obtain employment and, and evidences that this process has been occurring for some considerable time is given in the quite disproportionate number of eastern islanders occupying senior positions in the public as well as the private sectors in Fiji's main towns. And yet, within this changed situation, the dimensions of substantial proportions of small island populations on larger islands, circular movement remains an important component of the internal migration. If this dimension of Fijian mobility requires consideration some of the consequences of colonial intervention differ from those reviewed above, this time with greater emphasis on deliberate relocation of elements in the indigenous socio-economic system, on continuity rather than change.

Explaining Circular Migration

Unlike the drift to towns, circular forms of mobility were not initiated by colonial intrusion in Melanesia. Throughout the western Pacific, population movement involving short-term as well as lengthy absences from place of usual residence was an essential part of customary social and economic systems. In eastern Fiji, for example, there were extensive interaction networks linking groups on small islands around the time of European contact - networks sustained by reciprocal exchanges of various kinds, marriage ties, and welfare (Bedford 1976b, p. 12). These traditional forms of circulation was high frequency oscillatory movement within and between islands associated with gardening, fishing, feasting and fighting: movement which generally involved participants in absences of less than one week from their villages of residence. Related to this were movements of longer duration often motivated by the payment of collection of tribute to the residence of local chiefs. These movements, which could only be acquired in certain areas, the negotiation of alliances with rural groups...

In addition to circular forms of mobility, there was also an explicitly long-term relocation. Two common reasons for individuals leaving their communities of birth for residence elsewhere were marriage and residence with maternal kin. Intermarriage of chiefly families on different islands was part of a deliberate policy to strengthen alliances and weaken rivalries. Fijians can claim special customary privileges in the community where their mother was born; the place was a refuge in times of trouble and, especially, during the introduction of wage labor. People were group migration associated with the division and relocation of communities. Some groups in the population were much more mobile than others, and the spatial domains over which movement took place were often quite limited. There was nothing 'static' about traditional society.

Over the last 120 years there has been both continuity and change in Fijian mobility systems. The short-term oscillatory movements described above have a dual dimension of subsistence and social activities have persisted to the present. Some new nodes have been added to the complex of inter-island circulation networks, notably trading stores, schools, and churches. Migration following marriage has continued, especially for women and, while Fijian villages are now only rarely relocated, the process of community division and re-formation still goes on. There have also been obvious changes. Larger, long distance voyages for the purposes of collecting tribute, engaging in war, or trading local produce have disappeared from the mobility scene. Perhaps the most dramatic change, however, came with the demand for labour to work on plantations and later in towns. Circular labour migration not only served to strengthen some traditional mobility circuits; it added a new dimension to social and economic activities throughout Melanesia.

The condition of 'dual dependency'

A process which frequently evolved under colonialism was circular wage labour migration. The introduction of a capitalist mode of production cheap labour was required to work foreign-owned plantations. In addition, it is possible to identify a cross section between urban and rural economies. Fijians were employed to encourage men to seek wage work outside their rural communities. It was generally assumed that these seeking wages had limited pecuniary wants and would return to their villages only once they obtain 'target' incomes. Consequently policies of paying low wages (to ensure some stability in workforce) and providing the minimum accommodation for a temporary male labour force were often adopted.

This convenient rationalisation of the host population's response to wage employment in times of default was anathema, especially in Africa and the Pacific Islands. The net result was that indigenes could guarantee social and economic security more readily through participation in rural-based activities (subsistence as well as cash crop) and periodic wage employment. Circular labour migration was thus a mechanism - in some places voluntary, in others institutionalised and sustained by policies of the state - whereby members of the indigenous population sought their livelihood through their own two economic systems within the colonial state. Wishing or being compelled to retain the security of their traditional institutions, generally associated with residence in rural communities, while obtaining some benefits from involvement in non-indigenous economic activity, they circulated between villages and the centres of wage employment - plantations, mining settlements and towns.

A transnational condition?

Except where political policies have continued to hinder long-term settlement of indigenes in towns, or where the conditions of employment at certain destinations - for example, plantations - do not favour permanent relocation in those areas, circular labour migration is generally regarded as a transitional or compromise form of movement associated with the shift from the subsistence to the market economy. This is a complex and changing process, and the changing aspirations among people as activities become commercialised, have to particular localities are assumed to weaken. Improvements in transport and communications facilitate mobility, and with increasing diversification between areas as industrial and urban centres evolve, the necessary conditions for movement, or at least the capacity for long-term relocation emerge. It is in this context that internal migration is viewed as an equilibrium mechanism in a dynamic economy where 'new opportunities are continually created in places to which workers must be drawn, and old enterprises are ruthlessly abandoned when they are no longer profitable' (Lee 1966, p. 52).

Circular migration in an open labour market

In some areas, however, the dual dependency created by colonial intrusion has proved remarkably durable, even though the institutional framework underpinning the circular labour migration evolved has been substantially modified. In island countries of the western Pacific, for example, government regulations...
Introduced early in the colonial period in order to control movement of Melanesians to town have long since been withdrawn. Almost everywhere, Melanesians are free to leave their rural communities to seek employment in urban areas. The response to this much more appealing market has been a "ruthless abandonment" of old enterprises when they were perceived to be less profitable than the alternative. This situation whereby indigenous actively retain access to productive resources and socio-political rights or privileges in rural areas, while participating in the wage economy, has emerged as a relatively stable compromise.

For the great majority of those who make up the urban immigrant populations which can be identified in many African and Pacific censuses, rural communities remain 'home' in a sense which they never did in the history of rural-urban drift in the western world. Deliberate retention of close ties with people and events in their villages does not preclude the migrants from spending a considerable part of their lives in towns. But as Elkan (1976, p. 706) recently stated, reassessment is taking place in the African and Pacific mobility literature:

- the rural society to which they intend eventually to return is the direct source for them to fall back upon unless they take active steps during the whole of their urban living to contribute to its continuity.

**Circular migration and risk minimisation**

Mitchell (1969a, p. 177) expressed the view that where circular migration prevails there appears to be an appreciation on the part of the migrants of the relative strength in the urban areas, which are the centres of the urban society and to which they consider return possible. Successful return to their villages would involve certain degree of economic security, while reciprocal social obligations of kinship enable support in times of stress. In other areas employers' policies or high land values may prevent permanent settlement, or the income derived from full commitment to wage labour may not be considered sufficient compensation by the migrant for abandoning an active rural-based economic enterprises. Circular migration thus facilitates

compromise between the traditional social and economic system and the market-exchange economy introduced by colonialism. Various explanations have been offered for the persistence of this form of mobility in different Melanesian contexts (see, for example, Bedford 1974a; 1974b; 1975a; 1976a; 1976b; Chapman 1974, 1976; Chapman and Prothero 1977). One explanatory generalisation is outlined in the context of the evidence on population movement in eastern Fiji presented in the previous section.

**A rural-based explanation**

The pattern of behaviour evident in circular migration can be explained within the premise that decisions to move are intended-ly rational. However, a behavioural model based on the assumption that individuals attempt to maximise monetary gains through movement such as the one proposed by Todaro, cannot adequately explain this type of mobility. Only if it is assumed that participation in activities in both the villages and other areas is a necessity can circular migration be said to be maximising economic returns. Such an assumption is no longer valid for most Melanesians: options for satisfying a demand for non-monetary needs, for example by cash cropping in the village or through wage employment in town; it is not essential to participate in both, and attempts have also usually result in achievement of sub-optimal returns in a strictly economic sense. More relevant in the contemporary migration, is the notion of risk minimization. As Brookfield (1970) has argued, in the game against a rapidly changing world, Melanesians retain the security of the traditional system while making selective use of opportunities for gaining perceived benefits of the foreign commercial system. In this way they can minimise risk as disadvantaged by residents of the rural communities, while utilising a growing range of options for economic activity.

Most Melanesians wish to retain access to land for subsistence gardens and cash crops, as well as rights to participate in social activities in the village. They have deep psychological attachments to the rural communities where they or their parents were born, and where most have resided for a significant proportion of their lives. To satisfy their various social and economic needs, they adjust during their lives, strategies that ensure that a range of activities in villages as well as other locations can be pursued. For most adult males, subsistence gardening and wage labour are the only available viable options. Others may include cash cropping, sale of handicrafts, various types of government service, as well as temporary withdrawal from the monetary economy and utilization of savings and traditional cash crops in the rural-subsistence system (Brookfield and Hart 1971, p. 252).

A combination of circumstances may favour concentration of inputs on a particular activity in a certain locality, but the majority will strive to maintain their freedom of choice, and minimise risk rather than maximizing incomes, by balancing the uncertainty of their 'known world' against the uncertainties associated with full participation in the market exchange economy. Where access to land still depends on membership of a social group and continuing interest in village affairs, physical involvement in rural-based activities remains important for most Melanesians. Long-term absences can result in loss of social prestige and even rights to land.

**Relevance of the risk minimisation model to the Fijian case**

The relevance of this explanatory generalisation to the contemporary migration behaviour of Fijians born in the eastern islands does not appear to have been considered. Most of the small islands were in residence there in 1976. Recent migration histories for a small sample of resident留在岛 has contained few references to visits to their natal villages. Information from those still in the villages on islands like Kebara suggested that most of their absent kinmen had not returned since leaving for Vititi Lava. On the basis of these findings, it is quite apparent that a significant proportion of Fijians from the eastern islands are not endeavouring to utilize a wide range of options for economic activity in rural as well as urban areas. An absence of direct participation in village affairs is not, however, evidence of a total lack of interest in developments in their family. Although the long-term urban residents stressed they would like to go back to the village more frequently but this was just not feasible given the real and perceived inaccessibility of islands, many of which have experienced deterioration in both the frequency and regularity of shipping since the 1950s, leading them to Viti Levu (Unesco/UNFPA 1977, p. 261-263; Brookfield 1977). For those with salaried employment in the urban sector, the opportunity for protracted absences are not possible if they wish to retain their jobs. The risk of being attracted to the various informal social networks transport back to town is too real, as some project members discovered for themselves when working on the more isolated islands, where transport links between the centre and parts of the periphery are much better, such as on the three islands with conferred affields (Lobu, Ovalau and Taveuni). But with its fishing boats, there is much more short-term movement of people between town and village.

The question of land rights

Another partial explanation for less intensive involvement of urban Fijians in rural activities than might be expected from the evidence in other parts of Melanesia, is to be found in the land tenure system. Under the colonial administration Fijian land tenure was codified in great detail. This had the effect of making a relatively flexible indigenous system much more rigid. Every Fijian farm was legal in property in his father's matogai. It is irrelevant whether the father or child has never lived in the area, or whether the Taiwan and Batiki with its fishing boats, there is much more short-term movement of people between town and village.

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an outsider from a different cultural background, conscious of the limited natural resources of the island, its isolation, and small range of amenities and facilities, to encounter a group of young men who had spent most of their formative years in Suva, and had achieved good secondary education in town. Most of these returnees cited essentially non-economic reasons for their presence, such as looking after elderly parents, providing for a widowed mother and younger kin, or helping rebuild relatives homes destroyed in the coastal hurricane of 1973 and 1975.

In spite of a traumatic period of readjustment to the demanding physical work associated with gardening, fishing and repairing damaged buildings, as well as to the restrictions imposed by villager elders on certain types of social activity popular in town - western-style dancing and drinking alcohol especially - these men claimed they were finding village residence sufficiently satisfying and had no plans for returning to live in the city. They repeatedly contrasted the virtues of freedom and variety in village life with the more regimented, clock-bound and limited life in Suva. The opportunity to choose whether and when to go fishing, visit the gardens, make handicrafts, or just sit around talking, was highly valued by those who had experienced the 0800-1630 routine of laboured, office work or factory employment in town. Their views are admirably summed up in a comment made by a resident in one of the most remote parts of Fiji’s small island periphery (Korotuma) to an alien visitor some years ago: 'I feel sorry for you white men: you have only one way of life to choose from, whereas we have yours but our own as well' (Howard 1963, p. 66).

A declining proportion of Fijians from the eastern part of the country are choosing to exercise the options available for participation in two ways of life by circulating between village and town. The village is still 'home' to most Fijians in the spiritual sense that it represents their 'roots' (Racine 1973). But it is no longer true to say that rural communities in the small islands to the east are the permanent residences for the great majority of islanders. The dynamic centres of eastern Fiji social, economic and cultural activity are to be found now in migrant communities on Viti Levu (see Fig. 1).

A concluding comment

Adopted explanation of contemporary internal migration in any societal context requires consideration of a range of hypotheses relating to aspects of the movement process at both macro (societal) and micro (individual) levels. In Melanesia the focus of much recent inquiry has been at the micro-level - very few researchers have the statistical data required for adequate treatment of macro-dimensions of population movement. Detailed inquiry in salaried occupations has generated a wealth of information on the variety of circular forms of mobility - especially where the study has focussed on the movement behaviour of rural residents. In parts this has been an inevitable consequence of the variable definitions adopted for 'moves' - absences of 24 hours, a week, a month. The concern with circularity has also emerged from a deliberate attempt to derive more relevant theories of movement behaviour for different cultural contexts, than the so-called 'general' theories which were developed to explain certain types of internal migration in western societies. There has been a strong reaction against the focus on what Abu-Lughod (1975, p. 204) termed the 'central type of mover' in the western literature - the rural migrant who left his village for town in a large city quite removed geographically and in terms of easy communication from his place of origin.

In the project's mobility inquiries in eastern Fiji, there was an intuitive assumption that underlying the obvious net migration drift from small islands to towns that could be identified in the censuses, there was an intensive system of population circulation which was serving to keep the central focus of Fijian society in the rural areas. The term of internal migration was defined in such a way so as to ensure that short-term movements were not automatically excluded from the study. The methodology employed to collect field data - retrospective migration histories - tended to highlight circularity in movement behaviour. Yet, in spite of an inherent bias towards the identification of temporary forms of movement, the evidence from eastern Fiji suggests that circular migration from a rural base has been or is being replaced by what can only be termed a massive exodus from the villages. Explaining this exodus at the macro-level can be achieved, in large measure, with reference to hypotheses about the drift from rural to urban areas which have been devised in other cultural contexts. As argued earlier, there is nothing inherently unique or unusual about recent Fijian internal migration.

The trend towards decline in numbers resident in small island peripheries is a recent phenomenon in most parts of the south Pacific. Since the Second World War populations born on the great majority of permanently inhabited islands have increased substantially. Rising fertility levels at a time when death rates were falling generated a 'norm' of population growth. In some areas continuous net emigration had the effect of virtually removing the contribution made by higher rates of natural increase; in these places resident populations have tended to remain relatively stable. In others, the numbers enumerated in successive censuses since 1945 have grown rapidly. Except on some of the smallest and most isolated islands, or those acquired by foreign commercial and military interests, absolute population size of the indigenous population has not experienced for at least 50 years in most parts of the Pacific.

In the light of this modern demographic history, it is hardly surprising that the condition of declining resident populations in being viewed with considerable concern by some of those still living in the periphery. Net emigration, once considered a safety valve relieving pressure on limited land resources, is now perceived radically to be altering the structures of island populations. The accelerating exodus on young potentially productive (and reproductive) men and women is seen to be the cause of an increasing economic burden for those left behind to care for the children and elderly. In this short concluding statement some consequences of recent population movement from eastern Fiji are examined in the context of the view that rural depopulation has threatened the viability of rural communities on small islands. The discussion focuses on the demographic situation; the wider implications of migration trends for social and...
economic developments in the source and destination areas are not considered here.

PERCEPTION AND REALITY: A COMMENT

In a stimulating examination of recent demographic trends in one of the outer islands (Tauliki) of the Cook group, Graves and Graves (1976) drew attention to an interesting paradox which has emerged with reference to population changes on many small islands in recent years. Records of departures from Atauro during the early 1970s demonstrated that the equivalent of ten per cent of the island's population was leaving each year - dynamic confirmation of the casual perception of residents that their young people were leaving in droves and that, as a result, the population was declining rapidly. And yet, an analysis of the island's demographic history revealed that since 1945 there had been no depopulation in a real sense. Numbers resident had remained remarkably stable, around 2500 at each census count and changes to the age-sex structure had been minimal over the previous decade. Graves and Graves (1976, p. 454) commented that, regardless of the fact that the majority of people were younger than 40, in the production sector, the young people were being lost and because of this the overall population distribution had not changed in a way which might be expected.

Indeed the number of dependents supported by the average adult on Atauro had fallen in recent years - the residents simply experienced lower birth rates. In the productive sector, these two factors - the loss of younger people and the reconstruction of the age-sex structure by Graves and Graves highlighted the following trends: high fertility levels for at least 30 years which served to generate a surplus of young people up to the present; growing involvement of adult men in cash-earning activities so that the average household head has come to feel more keenly than ever the need for help of his older children to provide food for the family; greater dependency on imported foods which, given their high prices relative to the returns from wage employment or cash cropping, has led producers to become more conscious of the costs of dependents; a shift over the last 30 years in the economy, from the small unit of foodstuffs purchased foods in the diet, and the decline of inter-island group economic and social activities which for a long period was engaged in an earlier report (Unesco/UNFPA 1977), have much greater relevance for the perceived

hardship expressed by residents in the peri-

phery than the changes and sequences of net emigration. However, having observed that population movement has not yet led to an overall depopulation and that there are available Pijians labour force in the region as a whole, it must be noted that the effects of net migra-

tion have not been transferred everywhere in east-
ern Fiji. The smaller the island population, the greater the potential for structural imbalance and perinatal aggravation in any demographic process. Generalizations at the province level must be qualified consistently by reference to diversity. The roots of dissatisfaction with life in the periphery are deep and varied but they are not yet essentially demographic. A discrep-

ancy between the perceived and real con-

sequences of population movement for the sizes and structures of resident groups can still be found. One implication for the demographic development of the periphery of continued heavy net migration coupled with lower levels of fertility will be the

achievement of perceived structural imbalance in the not too distant future. As Ward (1967, p. 96) remarked over a decade ago: 'such a prospect seems remote, but it certainly seems that a number of the smaller islands will cease to be viable socio-economic units as present trends in culture change continue'. The important question is how, rather than to try and change the direction of demographic development in areas such as eastern Fiji. In the light of the above, it is worthwhile, and a range of alternative develop-

ment strategies for the small island periph-

ey have been outlined (Unesco/UNFPA 1977). But the real decision will be made by those 'communities of Stewart natives ... who are meeting and solving difficult problems in in-

genuous ways' (Thompson 1940) in islands which many former residents and current policy-makers describe as 'beautiful, but not places to live'. These questions are taken up in a policy context in the concluding part of this Technical Note.

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Population pressure, resources and welfare: towards a more realistic measure of carrying capacity

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I. INTRODUCTION

From its inception, a major goal of Project 7 of the UNDP Programme, and of the Fiji project in particular, has been improvement in the means whereby the relationship between a population and its resources can realistically be quantified. Much of the decision-making that affects our environment could be placed on a more rational basis if the decision-makers had at their disposal means of measuring this relationship that were based on accepted and reasonable criteria. At present, however, only approximate methods are available to planners. In development planning, for example, it is not possible to calculate with precision the capacity of a region or an island to support a growing population, without making rigid or unrealistic assumptions about ecological, social and behavioural factors. In the social sciences, too, the concept of 'population pressure' is fundamental to a very large area of explanation, without the means existing at present whereby this assumed pressure can quantitatively be assessed.

In the case of eastern Fiji, the data presented in the project's first general report (UNDP/UNFPA 1977) made it clear that none of the islands are 'overpopulated' in any conventional sense, even though the majority have, nonetheless, been losing population at an accelerating rate in recent years. This out-migration is partly due to the economic and social problems of outer island life in the 1970s, and is partly a response to perceived opportunities elsewhere in Fiji (see Bedford, this volume). Out-migration in these circumstances is surpris-

II. STANDARD POPULATIONS IN THEORY

THE PROBLEM

Population pressure is an important concept for both planning and the social sciences, but it has also proved to be strikingly elusive. The range of social phenomena have been explained as the result of excessive numbers pressing upon inadequate resources. At the same time, however, we have been concerned with adoption, migration and changes in settlement pattern. Population pressure plays a prominent role. However, in order to define population pressure we must have some idea of the point at which a given society will reach, or at least approach, the limits of its available resources. To define resource levels we must consider the productivity of the ecosystems that a given society exploits, in relation to the technology, aspirations, and social organization of the society in question. Only if we can fulfill these data requirements shall we be in a position to answer the relevant questions, which are:

- how many people would the technology of a given society support in a particular environment at a certain welfare level?
- at what stage, therefore, would population growth likely to result in a deterioration in welfare?

An answer to the latter question, the deterioration in welfare, is likely to be perceived as 'population pressure', and which will be the trigger of social responses in an attempt to improve the situation.

Carrying capacity

Since at least the time of Malthus, there has been informed discussion of this subject. In recent years many writers have focussed on the quantitative definition of carrying capacity, where the question becomes:

- what is the carrying capacity of a given area of land for a human population?

This paper explores ways of providing some numerical answer to this question. An answer is needed which will be less simplistic than that provided by the usual man-land ratios of carrying capacity formulae (Street 1969; Porter 1970; Feachem 1973; Boserup/ERFA 1977).

To be of practical use, however, the answer must be more precise than the vague conditions about the difficulty of defining parameters which a strictly honest answer to the question perhaps demands. This paper starts with the assumption that overpopulation, or the state which prevails when the carrying capacity of an area has been exceeded, is a condition sometimes recognizable through various objective indicators, such as malnutrition, migration, social disorder, but usually only definable by reference to subjective states of mind, such as overcropping, unpleasant diet, excessive work-load, unacceptable distribution of settlement, etc. These perceptions are difficult enough to assess in an ethnographic context; in an historical one, proper assessment will be impossible. Quantifying the unquantifiable is sometimes a necessary academic practice, but it is justifiable only if the essentially artificial nature of the exercise is never forgotten.

What controls population capacity?

For an agrarian society using a pre-industrial technology, the population capacity of a given area of land depends on six main variables (Clark and Harwell 1966, p. 69-80):

- the node of subsistence (hunter-gatherer, shifting cultivator, permanent cultivator) and type of agricultural enterprise;
- the quantity of surplus production, and hence available land, that is wanted for purposes of social status, prestige, social change or marketing (Brookfield 1972);
- the amount of time that is wanted or needed, both for non-productive work (e.g. house-building, warfare) and leisure;
- the extent to which the above factors are changing;
- the extent to which variability in seasonal conditions (e.g. the monsoon) may lead to peaks in labour requirements, and hence availability of available land;
- whether or not variability in the harvest between different seasons means that a surplus in output is perceived as providing a necessary assurance to prevent occasional famines.

In this paper, attention is focussed on the second and third of these factors: variability in output requirements and in leisure time requirements, and an effort is made to examine their effect on the levels of carrying capacity that can be defined. For this purpose, we assume that the type of economy can be specified, and that the rate of change is not so rapid as to vitiate our efforts at defining other variables. Such assumptions are necessary (although not justifiable in all cases) if any progress at all is to be made towards making quantitative statements about population levels. Similarly, we disregard the effects of seasonal and historical variability, which can dominate decision-making in environments subject to substantial fluctuation and which might become of growing significance in an era of widening climatic variability.

TOWARDS AN IMPROVED CARRYING CAPACITY MODEL

Two main variables must be incorporated in an improved model of carrying capacity.

- variable levels of output. Even in so-called subsistence societies man does not live by subsistence alone. Food-gaining activities may dominate the economy, but in addition there are forms of social production and trade production for which the prime motivation is not subsistence, but instead the achievement of social status or the gaining of goods obtainable only through some exchange mechanism. In as much as these categories of output occupy time and, therefore, are needed for subsistence, they must be included in any carrying capacity formula. Where cash crops are a significant part of a subsistence economy, unfavourable terms of trade usually available to a peripheral agrarian society may mean that its market dependence actually reduces the population level that a region can support. This would seem to be the case in the

- variable levels of labour input. The time available for productive activities depends partly on how much time is left over when other labour needs have been fulfilled, but partly too on what is perceived as a tolerable level of agricultural work input. Shifting cultivators primarily involved in subsistence production are generally accustomed to what would appear to other labourers as long work hours, due to intensively practising paddy rice cultivation; organised labour in industrialised countries, or non-agricultural segments of leisure. The duration of the necessary working week would appear to be as valid a measure of carrying capacity as the quantity of production achieved, and both measures should be made explicit in statements of change.

In the pre-industrial world, increasing output per person is incompatible with reducing work inputs per person. Usually, the producer either works harder for a more substantial material reward, or he achieves 'affluence' by wanting and producing less and in so doing reducing his leisure time. In other words, the intensity of production can vary. As a result, there can be no absolute level of output for a given soil and crop type; output is relative to the intensity of input, which itself is culturally constrained. Most approaches to carrying capacity fail to accommodate this fact. Implicit in any calculation is some average level of yield per unit area, which is taken as a practice from the actual yields achieved by a particular agrarian society exploiting its land at a particular level of intensity. It would be better, clearly, to restrict the term carrying capacity to the population supportable by the maximum level of yield compatible with an 'acceptable minimum' level of return to labour being achieved. What is 'acceptable' will obviously vary between different cultures, but cross-cultural comparisons indicate that for staple products a ratio of food energy output to labour energy input of 10:1 is generally close to or beyond the minimum acceptable (Rappaport 1967, p. 262; Harris 1971, p. 217; Leach 1966, P. 113; Leach 1975, p. 34).

If we accept such a definition of carrying capacity henceforward termed the 'K' population level, following Malthus and Wilber (1967), then the interesting question becomes this: what improvements in welfare - more leisure, or more income, or less physical activity - would be possible at lower levels of population than K or capacity level? For example, with a population in a given area, say an island, that was half the maximum level, how much less hard would the people need to work in order to achieve a given lifestyle? Alternatively, how substantial would be the production surplus that this smaller population level could achieve if the people were prepared to work harder? If such questions can be answered in a specific real-world context, then we can begin to make statements about population levels that might offer value to social scientists, where the social, psychological and political limits to population growth are as important or more important than the strictly ecological determinants of carrying capacity.

Necessary procedure

Before discussing possible applications of this 'welfare' approach to population levels, the procedure required for the calculation of these population levels should be specified.
Population pressure, resources and welfare

It is therefore hoped that 'Chiyun Island' will represent a realistic, albeit hypothetical, illustration of how predictions about future productivity levels depend so heavily on the intensity of cultivation that is being assumed by the investigator. It is obviously unrealistic to expect that the actual data used to calibrate the Chiyun model will apply precisely to any particular real island. In a few geographical situations one can envisage islanders practicing root crop and maize cultivation at low intensities, then switching to wheat at intermediate intensities, and finally rice at high levels of intensity. Nevertheless, it would be surprising if the range of energy yields per ha and per manhour assumed for Chiyun were greatly different from those that prevail in reality for any pre-industrial society.

Calculation procedure for Chiyun

It will be helpful to present data and calculations in the same step-by-step form used above.

Step 1. Territorial land use classification. We assume that Chiyun Island is 100 ha in extent, of which 100 ha is suitable for cultivation of the main staple crop, the remaining 50 ha being considered non-cultivable land, and is used for all other needs.

Step 2. Economy. We also assume that the Chiyun Island population consists of 80 per cent of its diet from the staple. The work of producing this staple is restricted to the adult male population (the 'producer'). The remaining 20 per cent of the diet is derived from fishing, collecting, animal husbandry, etc. We assume that it requires negligible powered labour, is the responsibility of women and children, and can therefore be disregarded in calculations concerning the intensity of cultivation by the producers. For simplicity, we further assume that at all levels of population density and cultivation intensity the proportion of the diet deriving from the staple crop remains constant at 80 per cent.

Step 3. Maximum acceptable intensity level. We assume, as suggested above, that when the average energy returns from a manhour of cultivation fall below 1750 kcal then the utility of the system would be seriously impaired and the acceptability of the system would be considered as the point at which an acceptable level of output has been reached. At this stage drastic remedial measures such as mass emigration must be envisaged. This maximum

Step 1. Definition of the territory available to the population, and its classification in terms of the areas suitable for different land uses.

Step 2. Definition of a feasible economy, in terms of the type of environmental exploitations (agricultural crops) and the proportion of the total energy (E) needs of the population that each product should provide. The production of certain food staples, for example, may be restricted or encouraged by nutritional factors or by cultural preferences, and if so the limits of these constraints should be specified.

Step 3. Specification of what is the minimum productivity level (E units/manhour) which will be culturally acceptable. Empirically 1750 kcal (7300 KJ) per hour appears to be, and is sometimes below, the minimum actual yield recorded for major economic activities in subsistence or part-subsistence communities.

Step 4. Specification of the energy yields for each major land use (E units/ha) at various levels of labour intensity around the maximum intensity level defined in Step 2. Such data, showing yields/ha in relation to yields/ha (manhours), will often be unavailable, especially for subsistence crops. Sometimes such data can be determined by field work, or through ethnographic comparisons. See Figure 1 for clarification.

Step 5. Calculation of K (Carrying Capacity) population. This is the population that will be sustained at subsistence level by the production of available land, exploited to the maximum extent compatible with the constraints imposed by Step 3 above. For its calculation, the land area specified in Steps 2 and 3 are combined with the maximum yields from the relevant land uses specified in Step 4. This generates a total energy output (sum of E units per unit area), the maximum number of people that this output can support can be calculated by assuming that subsistence needs will not require more than about 6000 kcal (3.5 x 10 KJ) per person per year (FAO 1974).

Step 6. Calculation of the average labour input per productive person that will be required to support the K population. The concept of 'productive person' itself requires definition, according to the assumed age and sex structure of the population and distribution of labour within it. This mean labour input (E/ha per person), where l is a productive person, is derived from the total energy output and the mean output/ha (assumed being 1750 kcal at K).

Step 7. Calculation of mean labour inputs at lower population densities than K (e.g., 0.5K, 0.5K, 0.5K). This exercise will again require the productivity curves for each major land use discussed in Step 4. A smaller population than K will clearly not need to achieve maximum yields per hectare, and in most activities this in turn permits higher returns per manhour. Since the proportion that each activity contributes to the total output is known (defined in Step 2), the total labour input that the various labour productivities imply can be calculated for each population density.

A WORKED EXAMPLE: CHIYUN ISLAND

For the purposes of illustration, data are presented here for population calculations on the imaginary island of Chiyun. The agricultural system of Chiyun is an amalgam of elements contained in three real-world societies: all pre-industrial in technology: rice farming in pre-1949 China (Ruck 1938), smallholdings growing wheat in Yugoslavia in the early 1950's (Clark and Haswell 1966), and small and root crop farming in Nigeria in the same period (Gall et al. 1956). As Clark and Haswell (1966, p. 83) have shown, these three agricultural systems normally span virtually the whole range of feasible land and labour intensities in pre-industrial farming (Table 1). On the smallest farms in China labour inputs approach 3500 manhours per hectare (65/ha), and food outputs per ha fall as low as 1300 kcal. At the other end of the scale, the largest food crops in Nigeria receive about 150 manhours per hectare, but yield 7800 kcal/ha. Smallholdings in Yugoslavia are in the middle of this extreme range (Table 1).
present a 1.01 ratio of food energy output per unit of labour input. As Table 1 shows, virtually all our data for Chyomig do in fact relate to energy yield ratios more favourable than 1.01.

Step 4. Productivity of land and labour. The data in Table 1 enable us to construct the productivity relationships for land and labour (E units per hectare, S units per man-hour) shown in Figure 2. In a generalized and interpolated form, this curve provides us with the necessary data for calculating standard populations for Chyomig. The maximum intensity level for Chyomig would be seen from Figure 2 to be around 0.45 million kcal/ha, representing the yield possible at 1750 kcal/h.

Step 5. Calculation of K, or carrying capacity population. At the extreme level of intensity, the 160 ha of arabic land on Chyomig Island will yield 645 m kcal of food energy. Knowing that this total represents only 80 per cent of the total data, and assuming an average energy requirement per person (S) of 800,000 kcal/yr, we can calculate the K population as follows:

\[ K = \frac{645,000,000}{800,000} = 1007.8 \]

or 1008 persons

This population represents the maximum that Chyomig can support at the ultimate level of intensity that is acceptable, and it is the population of Chyomig for which we restrict the term carrying capacity. This point is to be emphasized. On the data available, no greater population can be supported within the given constraints. Use of marine resources, introduction of an industry, or employment on other islands could raise the total, but this is not relevant in the present context.

Step 6. Calculation of average labour inputs per producer (pp) at K level. For this purpose we require assumptions concerning the demographic structure of the Chyomig population. We have already stated (Step 5 above) that adult males alone are responsible for the production of the staple crop. For simplicity, we now further assume that males constitute 50 per cent of the population, and that productive persons (pp), i.e. all active adults, make up 50 per cent of all males. At K therefore, Chyomig produces number 25 per cent of 1008, 252 persons. The mean labour input per producer is thus (from Step 8 in the specification stated above):

\[
\text{(Total E at K/mean E/pp) = (645,000,000/1750)} = 372 \\
= 1463 \text{ hrs/pp/week} = 28.1 \text{ hrs/week}
\]

This work input is of course restricted to that involved in producing the Chyomig staple. In addition, the producers would no doubt have other, non-productive work commitments, such as building houses, etc.

Step 7. Calculation of average labour inputs at lower population densities than K. In our example this step requires simply the use of the productivity curve for the staple crop, around which we assume the entire economy revolves. To take one example, the mean labour input at 0.9K is found as follows:

\[ \frac{15}{10} \times 1463 \text{ hrs/pp/week} = 2194.5 \text{ hrs/pp/week} \]

Figure 2. Land and labour productivity relationships used in the Chyomig Island analysis (data from Table 1).

Table 2. Data for calculating standard populations of Chyomig Island

<table>
<thead>
<tr>
<th>Population</th>
<th>CALCULATED POPULATION</th>
<th>PREDICTED MEAN WORK INPUT</th>
<th>(HARVESTS/PRODUCTIVE PERSON/ANNE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1 Blank entries in this table appear where the suggested population numbers cannot be supported by the island's agricultural resources at the postulated levels of surplus.

Source: Calculated from data in Table 1 and the text.
Population at 0.5X = 0.9 x 1008 = 907 (227 pp)

907 persons @ 800 000 kcal/yr = 725 600 000 kcal total diet

If the staple food portion of the total diet is 6.8, this constitutes 580 480 000 kcal.

Assuming that the entire arable area remains in cultivation, then we obtain the following yields:

580 480 000 kcal

100 ha = 5 804 800 kcal/ha

and from Figure 2 we obtain the energy requirement of each manhour (mh) as 2900 kcal.

580 480 000 kcal produced by 227 men at 2900 kcal/mh requires:

(580 480 000/2900)

227

= 822 mh/yr or 17 hrs/week

In this way we can see that having a population on Chiyung 10 per cent smaller than at 2 enables the working population to enjoy 11.5 hrs/week more leisure time. Similar calculations for even smaller Chiyung populations are presented in Table 2, and indicate that the smallest population that the Chiyung agricultural system will support is 0.25X, or one quarter of the surviving capacity population, and at this low density a mere 6.5 hrs/week of agricultural labour will support the population at subsistence.

Step 8. Graphical portrayal of aggregate energy yields per manhour (mh) and per hectare (ha). This step is unnecessary in our example, since Figure 2 serves the same purpose.

Step 9. Calculation of labour inputs for populations requiring a surplus above subsistence (2) level. In Table 2 the results of such calculations are shown when energy inputs are required from the island in excess of subsistence needs (2), to the extent of 10 per cent, 20 per cent, 30 per cent, 50 per cent, 100 per cent and 150 per cent of 3. Such surpluses might be required to fulfill exchange needs, or might be the means of supporting additional families who are not agriculturally productive, whether on the island or elsewhere. To give an example, suppose the 0.5X population wishes to produce 3 + 100 per cent. The calculations to determine the mean work input are as follows. We already know:

Population at 0.5X = 504 (126 pp), and

S at 0.5X = 403 200 000 kcal

Hence 3 + 100 = 806 600 000 kcal

Of this, 80 per cent derives from the staple crop, which therefore provides 645 120 000 kcal. This energy output requires an intensity level of 1770 kcal/mh (from Figure 2). Average work input may then be calculated as follows:

(645 120 000/1770)

126

= 2926 mh/yr or 56.3 hrs/week.

We can show, in fact, that without transgressing our minimum acceptable constraints of 1750 kcal/mh, it is not possible for Chiyung Island to support a larger population than around 500 at a welfare level of 3 + 100 per cent or above (in other words at more than double the energy output that is needed for subsistence). A number of such calculated labour inputs is shown for feasible population levels in Table 2.

Step 10. Formation of a matrix. The data in Table 2 can be displayed in graphical form (Figure 3). Interpreting from these graphs for different lengths of working week (15 hours, 20 hours, 25 hours etc.) provides us with data for constructing a matrix of standard populations, each representing the equilibrium number of people that Chiyung Island can support if all land is utilized at the specified level of labour intensity, and producing the specified amounts of surplus over and above subsistence.

Standard populations

A number of such standard populations is shown in Table 3. They range from almost 1000 people working 25 hours per producer per week and living at subsistence, to 390 people working 50 hours per producer per week and generating 3 + 150 per cent in production. Extreme amounts of labour input are only possible on Chiyung if small populations live at or close to subsistence level. Any substantial production of surplus for export or other purposes involves either harder work or a smaller population, and often both. These phenomena are, in fact, commonly observed responses to the economic development of subsistence societies. It would seem, therefore, that although the range of alternative populations that Chiyung Island could support is artificially large (for purposes of illustration), it is an example substantially faithful to the basic nature of the population-environment relationship in pre-modern agrarian societies.

Evaluation of the Chiyung model

Rigidity of the model

Before considering the practical difficulties of applying the standard population approach to real islands in the Pacific, it is worth summarizing the likely strengths and weaknesses of the model in general terms.

The first difficulty is the need to specify for a given population not only its existing land use and economy, but also likely variations in productivity at higher or lower population densities. Such data are seldom readily available, and even if these productivity variations can be specified the impact of new technologies may soon render the data obsolete.

A second problem stems from the assumption that the principal input into cultivation is human labour, and that output per manhour is therefore a good measure of perceived productivity. Clearly, this assumption becomes less valid where human energy is supplemented by the extraction of draft animals and especially machines, together with chemical fertilizers, weedicides and pesticides. Without major elaboration, therefore, this deficiency may restrict the model's domain to the earlier stages of economic development.

The use of energy units of output may also raise difficulties in societies where monetary values predominate, and where production of high-value low-energy products begins to replace the simple surplus of food staples.
Variations in taro yields
daro nevertheless remains important and locally dominant in the Pacific. For this reason, if we are to use taro in the standard populations model, we must be able to define the relationship between the surplus output and the productivity of the crop. Such data are not readily available. Yields and cultivation techniques are highly variable, for reasons discussed in Appendix 1. Data on yields are shown in Appendices 2 and 3, for dry taro only. This is a reflection of the fact that data on crop yields from the tropical lowlands achieve even better yields, in the range 17-21 t/ha, which are only slightly below the yields reported for Hawaiian commercial farmers in 1969 (22 t/ha). The most spectacular yields of wet taro, reaching 71 t/ha of fresh roots, have been noted in cultivation trials, occur only with substantial fertilizer inputs under lowland conditions.

Converting yields to food values
Two problems emerge in attempting to express these gross corn yields into some net food value. One is the virtual absence of published data on the proportion of the gross corn weight lost in wastage when transformed into the net (i.e., peeled) edible portion. The second problem is the variation that exists in the caloric value of taro. Wastage is in two forms, corns lost through rot, and peeling. In Fiji, it was estimated that losses from rot reduced the yield sold by farmers on outlying islands by 25 per cent by the time the taro reached the urban consumer. Wastage by peeling was estimated at 15 per cent, which is the same proportion that was found in the New Guinea Highlands by Kappagoda (1967). In both cases, however, the peeling wastage relates to large mature corms. In the case of small or daughter corms (corns), the loss is proportionately much greater. On Ontong Java atoll, where the taro is harvested at 3-4 months and so the whole crop is in the cormel category, a sample of 660 corns weighed on average 40.5 per cent less after peeling, and this weight reduction does not include further possible losses from rot. In this paper, 15 per cent and 40 per cent will be adopted as wastage figures for corms and cormels respectively.

It is unfortunate that in total taro yield figures the proportion of large to small corms is not specified. However, it is possible to estimate that "the contribution of suchc corms to [total] yield increased as plant population decreased. Such yields were not reduced beyond the net yields of taro" and decreased with decreasing water supply. In Appendix 4 are shown data from three-cropping systems on main corns to corns. For 9-15 month dry taro, this seems to average about 80 per cent main corms, 12-18 month about 34 per cent. To these proportions the two waste...
Labour requirements

The labour requirements needed to achieve these various yields of taro are not at all completely known. Surprisingly, nora is known about the productivity of taro in subsistence societies using hand techniques, than about the costs and benefits of the more modern methods used by market-oriented farmers in Hawaii and elsewhere. Detailed estimates of labour needs, using manual labour are shown in Table 7.

Table 7. Summary of wet taro yields, expressed on an annual basis

<table>
<thead>
<tr>
<th>CROPPER</th>
<th>METHOD</th>
<th>PLACE</th>
<th>ANNUAL CROP YIELD (m3/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsistence farmers</td>
<td>Highland valley bottoms</td>
<td>New Guinea</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>Lowland valley bottoms</td>
<td>Fiji, Lautoka</td>
<td>16.6 - 21.0</td>
</tr>
<tr>
<td>Commercial farmers</td>
<td>Wetland and lowland irrigated, mostly with fertilizer</td>
<td>Hawaii average</td>
<td>22.4</td>
</tr>
<tr>
<td></td>
<td>Lowland irrigated, unirrigated</td>
<td>Hawaii</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>Lowland irrigated, with fertilizer</td>
<td>Hawaii</td>
<td>73.9 - 89.4</td>
</tr>
</tbody>
</table>

Source: data in Appendix 3.

Table 6. Summary of energy yield from taro under different systems of management

<table>
<thead>
<tr>
<th>CROPPER</th>
<th>CROP TECHNOLOGY</th>
<th>NET ENERGY YIELD PER YEAR</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical subsistence</td>
<td>Dry</td>
<td>Extensive shifting culti-</td>
<td>2.205 - 9.27</td>
</tr>
<tr>
<td>farmers</td>
<td>taro</td>
<td>vation, intercropping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intensive shifting culti-</td>
<td>taro</td>
<td>3.646 - 10.27</td>
</tr>
<tr>
<td></td>
<td>taro</td>
<td>varion, unimproved soils</td>
<td>5.682 - 23.78</td>
</tr>
<tr>
<td>Tropical subsistence</td>
<td>Intensive shifting or</td>
<td>10.176</td>
<td>42.61</td>
</tr>
<tr>
<td>farmers</td>
<td>perennial cultivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>taro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical subsistence</td>
<td></td>
<td>9.498</td>
<td>39.77</td>
</tr>
<tr>
<td>farmers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical subsistence</td>
<td>Dry</td>
<td>Extensive cultivation</td>
<td>16.156</td>
</tr>
<tr>
<td>farmers</td>
<td></td>
<td>artificial fertilizers and avoidance of drought</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Intensive cultivation,</td>
<td>27.136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>artificial fertilizers, varion, unimproved sites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>multirich, multilayered</td>
<td>10.854</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>16.033</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>25.348</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>12.236</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>25.248</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>17.499</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multilayered</td>
<td>20.259</td>
</tr>
</tbody>
</table>

Sources: A. Assumes corn yield is 80 per cent large (15 per cent waste) and 20 per cent small (40 per cent waste). B. Assumes corn yield is 34 per cent large (15 per cent waste) and 66 per cent small (40 per cent waste). C. Assumes corn yield is 100 per cent small (40 per cent waste). In all cases, the net edible yield is converted to energy equivalent assuming 1.06 million kcal per kg (105 kcal = 0.187 GJ). Original yield data are shown in Tables 4 and 5.

Table 7. Estimates of labour needs in various sections

<table>
<thead>
<tr>
<th>WORK CATEGOR</th>
<th>PERSON-HOURS OF WORK PER HECTARE-YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARIEN</td>
<td>7126</td>
</tr>
<tr>
<td>SELENI</td>
<td>167</td>
</tr>
<tr>
<td>HEBSTER</td>
<td>2400</td>
</tr>
<tr>
<td>SOLONI</td>
<td>303</td>
</tr>
<tr>
<td>MARING</td>
<td>283</td>
</tr>
</tbody>
</table>

(Author's estimates, using data supplied in original sources; for sources see Appendix 6.)
PRODUCTIVITY OF LAND AND LABOUR

In the four examples discussed above, the recorded taro yields are almost directly proportional to the differences in labour input:

<table>
<thead>
<tr>
<th>Total Labour Input per ha/yr</th>
<th>Net Pool Energy Output per ha/yr (1st year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tavanui</td>
<td>2400</td>
</tr>
<tr>
<td>Tapuili</td>
<td>2355</td>
</tr>
<tr>
<td>Salama</td>
<td>2360</td>
</tr>
<tr>
<td>Malaita</td>
<td>910</td>
</tr>
</tbody>
</table>

An extensive review of the literature has revealed other cases where detailed surveys have been made of labour use, land use and yields. Although less numerous than one could wish, these studies do provide some basis for calculating the relationship between yield per hectare and yield per man-hour for taro as a subsistence staple (Figure 4). In all cases the same procedures have been used as those discussed above, in order to reduce gross to net production and net production to energy yield. Some details concerning the sources are given in Appendix 6.

In Table 8 a summary of these cultivation systems shows that in not all cases is labour intensity directly proportional to yield. In one case (Ontong Java atoll) this is because abnormally high labour inputs are needed to sustain perennial cultivation of taro in an unfavourable environment. In two other cases (Nasauku and Uafato) high labour inputs reflect an unusual situation of recovery from hurricane damage to other food supplies. In some cases (e.g. Tavanui) the mean values mask a great deal of known variability between farmers and between sites in accessibility, fertility, and cultivation intensity. Variations in soils and climates, and also the differing importance of taro in the different systems, mean that the duration of the period of cultivation and the period of fallow also are not directly correlated with either yield or intensity level.

Relationship of Land to Labour Productivity

In general, the relationship between the productivity of land and that of labour is sufficiently clear-cut for a tentative curve to be drawn (Figure 4), quite similar both to the idealised curve shown in Figure 1 and to the hypothetical Chilung example (Figure 2). Agricultural systems at the lower end of this curve are those where dry taro is grown more or less as a supplementary crop occupying poor land (e.g. Báloma). Alternatively, taro is intercropped with yams, sweet potatoes, bananas, etc. in mixed swiddens (e.g. Tsembagas Malaita), in societies where land is plentiful, and labour inputs into weeding, etc. need not be substantial. In either case the result is that yields are low (5-10 million kcal/ha), but output per man-hour is high, reaching 4-6000 kcal per hour of work, and probably more where the gardens are located close to the village.

In the upper part of the curve, on the other hand, taro is grown more intensively. In some cases, as dry taro, it forms the principal staple (e.g. Uafato, Slwa). In others, as wet taro, it occupies rather limited areas of poor land requiring water control, and is supplementary to other staples (e.g. Caingolima in Ontong Java, cacao in Nasauku). Yields are higher (10-15 million kcal/ha), but labour is less productive (below 3500 kcal per hour).

In many humid tropical environments a steady transition from one end of this spectrum to the other seems quite plausible. Population pressure or the drive to achieve a surplus could both encourage societies to move from extensive shifting cultivation of dry taro to semi-permanent and even perennial cultivation of wet taro, utilizing in the process an increasingly wide range of environments and requiring a growing commitment of
labour. In many cases it would therefore be reasonable to utilize a graph like Figure 4 in order to generate standard populations for food-dependent societies, but using local data where possible.

Responses to population pressure

On the other hand, few societies now exist which are largely dependent on taro. Population pressure in reality might well lead both to a more intensive use of minor resources like fishing, and also to a search for alternative agricultural staples. Two examples of what might ensue are shown in Figures 5 and 6. In Figure 5 the two intensification curves are shown adjacent to a possible curve for sweet potatoes in the New Guinea Highlands. Data for sweet potatoes are even sparser in the Pacific than for taro, but three studies from New Guinea suggest that at low intensity sweet potato cultivation provides yields and returns similar to taro (e.g. Tsomgas Maring), but that at

higher intensities the sweet potato possesses significant advantages (e.g. Kapauku, Raiapu Enga). Net energy yields per hectare exceed 20 million kCal, which is almost double those from taro. At intermediate stages it seems likely that the two crops have similar yields, but that sweet potatoes supply more food per hour of labour. If further studies confirm this difference, then the incentive behind the adoption of the sweet potato in New Guinea in the last three centuries becomes very clear: as a subsistence staple, its cultivation would seem to offer a much more attractive path of agricultural intensification than taro. The sweet potato will either provide superior yields to taro for an expanding population with limited land, or alternatively will provide a more substantial food surplus than taro per unit of extra labour, such as might be needed by a population stable in numbers but increasingly involved in large-scale prostitution or pig husbandry.

The pressure on minor food resources will also vary according to population density. Figure 6 shows data from four Pacific Islands which differ greatly in the area of reefs available for exploitation by subsistence fishersmen (Seyliss-Smith 1978b). Onotong Java has the largest fish consumption of the four populations and by far the most extensive reefs. Lamotrek is intermediate, and Lakeba and Koro in Eastern Fiji have quite restricted fringing reefs which must be used very intensively. The yield of fish per hectare of reef reflects these different pressures, being low on Onotong Java, intermediate on Lamotrek, and high on Lakeba and Koro. The

variations in yield per hour of fishing, on the other hand, show the opposite trend, with the highest productivity on Onotong Java and the lowest in the Fiji Islands. More research is needed before such findings can be properly incorporated into standard population models, but it is striking that the yields and productivity of marine resources should change with population pressure in a similar way to the yields and productivity of the agricultural crops.

IV. BATIKI ISLAND: THE STANDARD POPULATIONS APPROACH

Batiki are too drought-prone for root crops apart from a little cassava in recent years, but which are ideal for coconuts (70 ha). It is assumed in Table 9 that 10 per cent of these categories of useful land is occupied by settlements, paths, boundaries, fruit trees, etc., and is unavailable to crops. The fringing reef encircling Batiki has an area of 1410 ha of shallow lagoon and coral, and is used for fishing and the gathering of shellfish.

Some land uses are interchangeable between these various soil types. In particular, the moderate slopes with colloidal soils have been largely planted with coconuts during the present century, and so are not at present available for root crop cultivation. Admittedly, a little cassava is now grown beneath the coconut palms, but only where the coconuts are at low density. Batiki has a rather marginal rainfall regime, and for our model purposes it will be assumed that coconuts exclude root crops, and vice-versa.

The island economy

The economy of the island, past and present, has revolved around various ways of exploiting three main resources:

- Root crops. Taro and yams were the traditional staple food plant in coconuts (in season) breadfruit. Increasingly, since about 1910, cassava has replaced the traditional root crops; it provides more favourable yields on poorer soils, and also enables coconut planting to be extended to the most fertile sites. For our model purposes it will be assumed that these various root crops all vary in yields and productivity at various agricultural intensities in the same way as does taro (see Figure 4).

- Coconuts. Among its many other economic uses, the coconut palm provides an energy rich food usually eaten as coconut cream, and its leaves are excellent thatching material. Since the late 19th century the coconut has also acquired exchange value as near the end of the century, it was postulated that this which has now dominated the land use and economy of
the minimum level of exploitation that is feasible. At each level adjustments are made to the proportion of land assumed to be usable per year (i.e. the length of fallow), as shown in Table 9. At the three levels the cultivated land of Batiki will thus produce three different amounts of taro production. As a result, the amount of coconut and fish needed will also vary; as will the work load required to produce these two dietary supplements. Coconut work varies in fixed proportions with the required volume of output, but fishing effort will vary according to the relationship shown in Figure 6.

By calibrating the standard population model (see section 7) with these data, and by applying the dietary constraints as described, three standard populations for pre-colonial Batiki may be calculated:

### STANDARD POPULATIONS IN THE PRE-COLONIAL PERIOD

The pre-colonial model of Batiki Island populations assumes a subsistence economy with fixed consumption levels for fish and coconut, as discussed above. This economy represents the situation as it may have been before about 1870, although we should not forget that even before market trading had started some surplus of coconut oil and other goods was being produced on Batiki as tribute for the Bau chiefs. To meet this required surplus, and to cope with fluctuations in yield following possible drought or hurricane damage, the level of per capita energy demand in the model is fixed at 3 million kcal, about 20 per cent above the average subsistence needs (0.8 million kcal per capita).

Three levels of intensity in agriculture are considered (see Figure 4):

- High intensity level, representing virtually the carrying capacity (C) level for this particular technology and diet, with 13.5 10^6 kcal produced per hectare from root crops (i.e. taro), but with only 2000 kcal produced per ha.
- Intermediate intensity level (10.5 10^6 kcal/ha and 4500 kcal/ha).
- Low intensity level (4.5 10^6 kcal/ha, 7000 kcal/ha), representing something

Like the value of the crops will, of course, vary according to the prevailing price.

- Fish. Marine foods, predominantly fish, have always been important on Batiki, and in the 1970's they have also acquired some commercial value. We assume for colonial and pre-colonial times that fish provided nine per cent of the dietary energy, falling to half of this level at the present day as fished, and fish become available. We further assume that the productivity of fishing varies with yield per hectare in the way described by Figure 6.

### Level of Agricultural Intensity

<table>
<thead>
<tr>
<th>Number of Persons</th>
<th>Work Input per Worker (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supported at 1 x 10^6 Intensity</td>
<td>5.2 (28)</td>
</tr>
<tr>
<td>Supported at 1 x 10^7 Intensity</td>
<td>2.5 (20)</td>
</tr>
<tr>
<td>Supported at 1 x 10^8 Intensity</td>
<td>1.2 (18)</td>
</tr>
</tbody>
</table>

These figures suggest that in pre-colonial times Batiki could have supported between 280 and 870 persons depending on the intensity of environmental exploitation, with the corresponding work input per producer (assuming only 25 per cent of persons are productive) varying from 12.6 to 37.6 hours per week. These work inputs are for food-producing activities only, and do not account of such necessary activities as the production and maintenance of tools, houses, boats and other equipment, weaving mats and baskets, and other craft activities. Clearly, therefore, carrying capacity is likely to have been perceived by pre-colonial Batiki Islanders well below the maximum level (870 persons, 37.6 hours work) that the model suggests could have been supported.

Commander Wilkes spent several months in Fiji in 1840, and 'adopted the plan of counting the inhabitants wherever I had the opportunity, in order to check the estimate given to me by others'. Batiki, which was visited by some of his expedition, he estimated as having 500 inhabitants (Wilkes 1843, 3. p. 323). Using our model of the island economy at around this time, we can calculate the level of exploitation intensity and consequent work inputs required to sustain such a population. At the subsistence plus 20 per cent level,
and with the dietary constraints already described, 500 persons (125 producers) could be supported by 16.8 hours of work per week. This level of activity seems very plausible: subsistence food-gaining activities in Pacific societies not unlike Bartki all seem to require work inputs in the range 10-20 hours (Bayliss-Smith 1978b).

It can be suggested therefore, that both the population estimate of Wilken and its predicted implications can be taken as direct evidence that in the early 19th century the economy of Bartki had stabilized at just below the intermediate intensity level. To some extent, such a level must have represented the island's perceived carrying capacity. The structure of the island economy at this intermediate level, as simulated by the model, is shown in Figure 7.

**THE COLONIAL PERIOD (CIRCA 1954)**

The principal economic changes of the colonial period were the planting of coconuts in areas previously used for root crops, and the consequent adoption of more tolerant subsistence crops, notably cassava. The money earned from copra was spent partly on new consumer goods (clothes, hardware, soap, tobacco, kerosene), and partly on imported foods. On the nearby island of Koro average incomes by the late 1950's had reached $35 per capita, of which an estimated 42 cents per cent was used to purchase imported foods (Bayliss-Smith 1977a). Bartki is less suited than Koro for the growing of subsistence crops like yams, so for the 1950's it is a reasonable assumption that on Bartki 30 per cent of income would be needed for buying food. We further assume that an income level of $35 per person is required, and that the sole source of this income is copra. Moreover, the changing diet in the colonial period means that a maximum of 15 per cent of energy can come from copra, 9 per cent from fish (as before), and the remainder from root crops and imports.

With these assumptions, and adopting the same procedure as outlined above, the structure of the economy of Bartki Island can be simulated at the same three intensity levels. The year chosen is 1954, which represents perhaps the peak in colonial prosperity in eastern Fiji, with high copra prices and relatively cheap food, the latter estimated as supplying on average 12 500 kcal per dollar spent (Bayliss-Smith 1977a). This time, however, the range of predicted standard populations spans a rather narrower range:

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Number Supported at $555</th>
<th>Work per Producer per week (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>342</td>
<td>10.0</td>
</tr>
<tr>
<td>Intermediate</td>
<td>511</td>
<td>13.1</td>
</tr>
<tr>
<td>High</td>
<td>482</td>
<td>14.1</td>
</tr>
</tbody>
</table>

If all land was in use but at low intensity this economy would have supported a population of about 340, with only 10 hours of food-gaining or cash-earning work needed by each producer per week. Even at high intensities 25 hours of such work would have secured the specified level of food for a population of 480. For comparison with the pre-colonial model, the structure of the island economy at the intermediate intensity level is shown in Figure 8.

Whether or not the high intensity population can be taken as an accurate representation of the island's carrying capacity will depend (assuming the model to be accurately specified) on whether a minimum of $35 income and/or a maximum of 25 hours work are acceptable as levels of welfare for Bartki Islanders in 1954. It is known that in the village of Nacansak, on the neighbouring island of Koro, villagers had achieved this income level a few years later and were regarded by Wartars (1967) as being relatively prosperous. It is also known that in 1956 the actual population of Bartki was only 306 persons (McArthur 1958), and so below the minimum predicted by the model. Almost certainly, therefore, we can conclude that in 1954 by no means the whole island was under full cultivation: if it had been, the model would suggest that almost $50 per person in cash income could have been gained by these 306 persons, provided they were operating more or less in accordance with the model's assumptions. Such prosperity was almost certainly not reached on Bartki until several years later.

**THE MID-1970'S: A DEPRESSED COPRA ECONOMY**

Even if all suitable land had not been planted with coconuts in 1954, by the 1970's the commitment to copra was almost total. Most of the moderate colluvial slopes were planted with coconuts or in process of being planted and adequate arable land was becoming so restricted that in some places plots of cassava were being planted beneath the shade of coconut palms.

At the same time there had been a long-term deterioration in the real returns from copra, despite temporary boom periods such as...
chat of 1973–74. By 1975 coconut was fetching less than it had done twenty years previously ($76 per tonne compared with $83 in 1954), while inflation had severely diminished the purchasing power of money. The dollar in average store purchases gained only 5620 kcal in food energy in 1975, or less than half of its return in the 1950's.

These changes are reflected in the results of a standard population analysis. The welfare standard adopted for 1975 is $160 per capita per year, using once again the not unsatisfactory level that was being achieved by villagers on Koroi Island at this time. Such an income is modest by comparison with the income level regarded as adequate by planners dealing with sugar cane farmers elsewhere in Fiji (UNDP 1971), but since on Batiki (as on Koroi) over 40 per cent of the diet still derives from the subsistence sector, direct comparison is difficult.

For the model, it is now assumed that imports contribute 36 per cent of the diet, that coconut consumption has shrunk to Hardaker's 'acceptable minimum' of 100 nuts per person per year, or about 7 per cent of the diet, and that fishing has also declined in importance to 5 per cent of the diet. At 1975 prices, and with 50 per cent of the per capita income of $160 spent on food, Batiki Island will support the following populations dependent upon copra selling.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Number Supported</th>
<th>Work per Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>117</td>
<td>13.7</td>
</tr>
<tr>
<td>Intermediate</td>
<td>124</td>
<td>16.9</td>
</tr>
<tr>
<td>High</td>
<td>125</td>
<td>22.6</td>
</tr>
</tbody>
</table>

To satisfy the $160 requirement at the prevailing prices such a high proportion of land must be under coconuts that the level of agricultural intensity in subsistence crops (i.e. taro) makes little difference to the population supportable, which is around 120 persons at all three levels. The work load varies somewhat, but even so it is fairly modest (12 hours) even at high intensity, as a result of the economy's copra dependency: coconut palms do not produce significantly more when managed more intensively, so that the yield restriction in the area of field crops that a copra economy involves in effect imposes enforced idleness on a large part of the labour force. For example, at intermediate intensity level (Figure 9) the model predicts that some 260 ha of land will be under coconuts. Under a commercial plantation regime, as on Yavuani, on average 19 ha are maintained by labor per worker (Broadfield 1967a), so the management of these Batiki coconuts is scarcely a full-time job for the 124 persons (31 per cent) that Batiki could support under the intermediate intensity regime.

Actual vs. predicted in the 1970's

All of these standard populations are, however, much smaller than the actual population of Batiki in 1975, which, although declining, still numbered 227 persons. The actual population was therefore almost double the maximum standard population, in stark contrast to the situation in 1954 of underutilization of resources by comparison with even the low intensity model's result. In 1975, our model predicts that the actual 227 persons living on Batiki could only earn $86 per person per year if constrained by the diet specified above. Such an economy would involve only 17.3 hours of work per week in cash-earning and food-gaining activities, but it would also require that 95 per cent of all income be spent on imported foods. If we adopt instead the more realistic constraint that only 50 per cent of all income is available for work, then the model predicts that not only would a population of 227 need to produce 69 per cent of its total diet, but that also the transfer of coconut land to root crops means the required work input would be higher at 25.2 hours. Mean per capita incomes are similar at $89.

It is of interest to compare these predictions with the actual per capita incomes recorded in September 1975 (Bayliss-Smith 1978). Incomes averaged $127 for the preceding 12 months, but only $69 of this derived from exploitation of the land environment (mainly coconuts). An activities survey in September 1975 showed an average of 26.7 hours of food-gaining and cash-earning work per adult man, again quite close to the level suggested by the model (25.2 hours) when half of the income was assumed to be needed for non-food purposes.

Further evidence of the model's validity comes from the people's own perception of their position in 1975. They were well aware that Batiki Island had become overpopulated relative to welfare standards elsewhere in Fiji, and several were making arrangements to migrate to Suva to live with relatives at least until the terms of trade showed some improvement.
THE MID-1970’s: ALTERNATIVE ECONOMIES

The over-dependence of eastern Fiji upon a declining copra industry was heavily stressed in our first general report (Unesco/UNPFA 1977), and various alternatives were suggested. One solution that could be relevant to islands close to urban markets, like Batiki, is commercial root crop farming. The questions now being posed are as follows:

- if the coastal soils which have been planted with increasingly unproductive coconuts were converted to arable farming, what output of root crops could be achieved? and
- how would population capacity and work loads be affected?

If we add to the range of economic options available, the production of taro, using existing technology, for sale at 1975 prices, and if in the model we retain the same diet and procedure as described above for the 1970’s copra economy, we can calculate the following standard populations based mainly on taro selling:

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Number Supported (female)</th>
<th>Work per Producer (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>132</td>
<td>15.5</td>
</tr>
<tr>
<td>Intermediate</td>
<td>393</td>
<td>30.1</td>
</tr>
<tr>
<td>High</td>
<td>544</td>
<td>65.3</td>
</tr>
</tbody>
</table>

Up to five times more people could be supported with this economy than if they continued with copra, but at high intensities it is clear that the continued use of hand methods would involve prohibitive amounts of labour (65 hours per producer per week). If we consider the actual population of Batiki, however, then the 277 persons present in 1975 would achieve the standard income ($160) for only 26.8 hours per week. When compared with the predicted 89 and 25.2 hours for the copra economy (or for that matter the observed situation in 1975), then it is an alternative that most Batiki Islanders would be glad to adopt, assuming that marketing arrangements were satisfactory.

If commercial root crop production did replace copra on a large scale, then almost certainly minor technical innovations would be adopted to save labour. One of the first would be the use of Gramoxone (Parquat) herbicide, which is already widely used on Taveuni by Fijian and Indian small farmers growing taro for local markets. This killer costs only 325 per hectare treated, and vastly reduces the amount of tillage and weeding required. Data obtained from experiments by Raynes (1976) and the Taveuni data recorded by Hardaker (1976) enables us to estimate the following savings per hectare-year:

- low intensity: 10 per cent labour reduction
- intermediate intensity: 22 per cent labour reduction
- high intensity: 31 per cent labour reduction

The result on Batiki would be slightly to reduce the size of the standard populations supportable, but quite substantially to reduce the average weekly work loads.

COST

Intensity | Number Supported (female) | Work per Producer (hours)
Low       | 136                       | 17.3                     |
Intermediate | 321                       | 24.3                     |
High      | 534                       | 46.6                     |

In terms of both labour input and level of income ($160 as before), the intermediate intensity of cultivation becomes a highly attractive economy, supporting a population of 350 with only 25 hours of work per producer (see Figure 10). The actual 1975 population of 277 would only need 22.6 hours to produce $154 per capita. This is strikingly more favourable than the actual situation on the island in that year, when over 25 hours per week only produced $69 per capita from environmental sources.

CONCLUSION

It would be possible to elaborate the Batiki analysis still further by examining the effect of changing some of the other land uses, or by adopting different welfare assumptions. If this approach were to be used in actual development planning, involvement with the people concerned would be essential. For example, for adjustments to the Batiki model to be worthwhile, the Islanders themselves should be consulted in order to produce welfare standards that were perceived as being feasible. The point of the Batiki example is, however, merely to suggest that if the data problems can be overcome then standard populations can be calculated in relation to specified requirements of leisure and surplus. The deterministic character of the employing output approach can thus be abandoned in favour of this alternative approach, which is by nature more flexible and more realistic.

ACKNOWLEDGMENTS

The argument proposed in this paper owes much to discussion with my colleagues in the Unesco/
VARIATIONS IN TARO CULTIVATION

Now is known about the yields of taro than about the crop's labour requirements, but we know relatively little about the principal reasons for variations in yield, and the whole question is complicated by the proliferation of numerous cultivars, many of which have different growth responses.

Crop period

A recent review of taro suggested that the normal crop period varies between 6 and 12 months (Plunkett 1979). In Fiji, recent growth trials confirm the generally accepted view that taro comes mature after 9 months of growth (Haynes 1979); after 9 months the plants continue to grow, but in wet areas there is a risk of losses through stem rot after 10-12 months. In Eastwood, some are harvested at 8 months. In Vanuatu, on the other hand, 12-14 months is the most normal growth period (de la Fera 1970). A much shorter cropping period is adopted in the Solomon Islands, where taro is usually cropped and replanted at least twice a year. Gilliver (1970) found in trials on over 150 Solomon Islands cultivars that the crops were mature within 144-186 days (mean 172). On Otago Farm all but the Solomons most taros are harvested only 9-13 months after planting, and although some varieties can be left for up to 5 months the taste deteriorates and the risk of stem rot increases. In the Mount Hagen region of the New Guinea Highlands some cultivars are ready after 4-6 months, but others require 18-22 months (Boccelli et al. 1972). A growing season of 6 months is normal in Egypt (World 1970). These variations may influence considerably the annual yield figure.

Latitude and altitude

Other factors of importance are soil radiation levels, water supply, soil nutrients, and plant spacing. Sunshine differences have been suggested in Hawaii as the principal reason why high rainfall valleys have lower yields than drier coastal sites (Clarkson and de la Fera 1971) and the southern states of the United States of America (Greenwell 1947), where long day lengths during the summer may compensate for the brief growing season. In the tropics taro can also be grown at altitudes; in the New Guinea Highlands, for example, taro is common up to about 2100 m, and in places is found as high as the sweet potato, at 3000-3750 m (Golson 1977). At altitudes over 2000 m the minimum temperature in New Guinea is around 10°C or less and maximum seldom reach beyond 20°C, which is the level claimed by Greenwell (1947) as optimal for taro growth.

Seasonality

In the humid tropics, taro does not display marked seasonal periodicities in growth. A distinction should, however, be made between wet taro grown under irrigated conditions, and dry taro which depends directly on rainfall for its water supply. Provided that daynight temperature reach about 16°C, wet taro will grow continuously, and can be planted at any time of the year. Dry taro, on the other hand, may grow more favourably if planted at certain seasons, since the young plants are sensitive to drought. In Fiji, for example, any taro planted in April-September tends to be affected by dry season (Golson 1970). As a result, production for the urban markets also reaches a peak in the last or first quarters of the year (Kundaker 1976).

Spacing and nutrients

Cloudiness, water supply, nutrients and spacing are interrelated in their effect on taro yields. In Vanuatu, for example, where taro is always irrigated and is usually fertilised, solar radiation is low in the high rainfall valleys as a result of the heavy cloud cover. Here spacing is generally wide, as much as 90 x 90 cm (11-90 plants per hectare), whereas on the
coast the plants can be spaced more densely (40 x 60 cm, 25,870 plants/ha). The average in Hawaii is about 40 x 60 cm (16,800 plants/ha) (Plunkett and de la Pena 1971). In the wet zone of Fiji, Leon, Pitsi Siitam (1970) found that unmulched plots had a yield of 15.8 cm (90 x 90 cm) gave yields 25% per cent higher than when the plants were grown more densely (40 x 60 cm). Spacing the soil with nitrogen, however, resulted in yields in the denser plots being located to 187 per cent of the yields in the more widely-spaced plots. Interestingly, almost on big an increase in yield was achieved in the denser mulched plots in this experiment by ensuring the soil sur-
face between the plants with a plastic film 'mulch', a finding also reported from Japan (Nagash). Green mulching is provided by various farmers in the Pacific to achieve the same effect. On Onong Java 30%.

APPENDIX 1. Yield of dry taro

<table>
<thead>
<tr>
<th>PLACE (SOURCE)</th>
<th>METHOD OF CULTIVATION</th>
<th>SPACING (cm)</th>
<th>PERIOD (months)</th>
<th>CORN YIELD (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands: Dala, Malaita (British Solomon Islands Protectorate 1969; Soloman 1970, 1972)</td>
<td>General average for subsistence cultivation</td>
<td>n.s.</td>
<td>7-12</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Harvest &quot;when mature&quot; of 187</td>
<td></td>
<td>(12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solomon Island cultivars grown on land newly cleared from secondary forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. October-May, three seasons</td>
<td>90 x 60</td>
<td>5.4</td>
<td>5.60</td>
</tr>
<tr>
<td></td>
<td>B. May-October, two seasons</td>
<td>90 x 60</td>
<td>5.4</td>
<td>4.85</td>
</tr>
<tr>
<td></td>
<td>C. May-October, 1969, with 168 kg/ha plot</td>
<td>90 x 60</td>
<td>5.6</td>
<td>6.03</td>
</tr>
<tr>
<td>Guinea: Fijian Weather Coast (Chapman and Pirie 1970)</td>
<td>Output from taro holding 32 households (4.095 ha) during 560 household days</td>
<td>n.s.</td>
<td>n.s.</td>
<td>2.09</td>
</tr>
<tr>
<td>Fiji Islands: average (Galesey 1969)</td>
<td>91 plant, various soil, various</td>
<td>154 x 154</td>
<td>(12)</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>crops, in FAD Census of Agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A block of 30 plants grown by each of 5 different farmers, volcanic soils</td>
<td>about 80 x 90</td>
<td>10</td>
<td>9.3-10.6</td>
</tr>
<tr>
<td></td>
<td>Agricultural trials on black soil with residual fertilizers, 7 best-yielding local cultivars</td>
<td>n.s.</td>
<td>7-10</td>
<td>10.4-12.6 (av. 10.83)</td>
</tr>
<tr>
<td></td>
<td>Alluvial soils, lower Rewa Valley, trials</td>
<td>n.s.</td>
<td>7-10</td>
<td>14.6-17.8 (av. 16.23)</td>
</tr>
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<td></td>
<td>A. Average of all cultivars, spacing trials</td>
<td>n.s.</td>
<td>7-10</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>No fertiliser</td>
<td>90 x 90</td>
<td>7-10</td>
<td>7.4</td>
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<tr>
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<td>No fertiliser</td>
<td>90 x 60</td>
<td>7-10</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>No fertilizer, but plastic film mulch</td>
<td>90 x 60</td>
<td>7-10</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>50% Survey of Indigenous Agriculture, based on year's output from 20.6 ha at Suva, volcanic soils, moderate rain</td>
<td>n.s.</td>
<td>(12)</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>Two intercropped with other rows and vegetables in mixed paddies; tara energy yield is 30 per cent of the total</td>
<td>n.s.</td>
<td>12</td>
<td>2.64</td>
</tr>
</tbody>
</table>

APPENDIX 2. Yield of dry taro

PLACE (SOURCE) | METHOD OF CULTIVATION | SPACING (cm) | PERIOD (months) | CORN YIELD (t/ha) |
<table>
<thead>
<tr>
<th></th>
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<tr>
<td></td>
<td>No fertiliser</td>
<td>90 x 90</td>
<td>7-10</td>
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<td></td>
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<tr>
<td></td>
<td>Two intercropped with other rows and vegetables in mixed paddies; tara energy yield is 30 per cent of the total</td>
<td>n.s.</td>
<td>12</td>
<td>2.64</td>
</tr>
</tbody>
</table>

APPENDIX 3. Yield of wet taro

PLACE (SOURCE) | METHOD OF CULTIVATION | SPACING (cm) | PERIOD (months) | CORN YIELD (t/ha) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands: Dala, Malaita (British Solomon Islands Protectorate 1969; Soloman 1970, 1972)</td>
<td>General average for subsistence cultivation</td>
<td>n.s.</td>
<td>7-12</td>
<td>7.6</td>
</tr>
<tr>
<td>Western Samoa: Upotapo (Lockwood 1973)</td>
<td>Harvest &quot;when mature&quot; of 187</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solomon Island cultivars grown on land newly cleared from secondary forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. October-May, three seasons</td>
<td>90 x 60</td>
<td>5.4</td>
<td>5.60</td>
</tr>
<tr>
<td></td>
<td>B. May-October, two seasons</td>
<td>90 x 60</td>
<td>5.4</td>
<td>4.85</td>
</tr>
<tr>
<td></td>
<td>C. May-October, 1969, with 168 kg/ha plot</td>
<td>90 x 60</td>
<td>5.6</td>
<td>6.03</td>
</tr>
<tr>
<td></td>
<td>Output from taro holding 32 households (4.095 ha) during 560 household days</td>
<td>n.s.</td>
<td>n.s.</td>
<td>2.09</td>
</tr>
<tr>
<td></td>
<td>91 plant, various soil, various</td>
<td>154 x 154</td>
<td>(12)</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>crops, in FAD Census of Agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A block of 30 plants grown by each of 5 different farmers, volcanic soils</td>
<td>about 80 x 90</td>
<td>10</td>
<td>9.3-10.6</td>
</tr>
<tr>
<td></td>
<td>Agricultural trials on black soil with residual fertilizers, 7 best-yielding local cultivars</td>
<td>n.s.</td>
<td>7-10</td>
<td>10.4-12.6 (av. 10.83)</td>
</tr>
<tr>
<td></td>
<td>Alluvial soils, lower Rewa Valley, trials</td>
<td>n.s.</td>
<td>7-10</td>
<td>14.6-17.8 (av. 16.23)</td>
</tr>
<tr>
<td></td>
<td>A. Average of all cultivars, spacing trials</td>
<td>n.s.</td>
<td>7-10</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>No fertiliser</td>
<td>90 x 90</td>
<td>7-10</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>No fertiliser</td>
<td>90 x 60</td>
<td>7-10</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>No fertilizer, but plastic film mulch</td>
<td>90 x 60</td>
<td>7-10</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>50% Survey of Indigenous Agriculture, based on year's output from 20.6 ha at Suva, volcanic soils, moderate rain</td>
<td>n.s.</td>
<td>(12)</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>Two intercropped with other rows and vegetables in mixed paddies; tara energy yield is 30 per cent of the total</td>
<td>n.s.</td>
<td>12</td>
<td>2.64</td>
</tr>
</tbody>
</table>
APPENDIX 4. Proportion of main crops (large) to minor crops (small)

<table>
<thead>
<tr>
<th>PLACE, SYSTEM OF CULTIVATION</th>
<th>TOTAL YIELD</th>
<th>PER CENT LARGE</th>
<th>PER CENT SMALL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(t/ha)</td>
<td>(corms)</td>
<td>(corms)</td>
</tr>
<tr>
<td>Hawaii uplands, dry taro:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. with fertilizer, 12 month</td>
<td>13.67</td>
<td>78</td>
<td>12</td>
</tr>
<tr>
<td>crop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. P and K fertilizer only</td>
<td>6.69</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>12 month crop</td>
<td>7.32</td>
<td>79</td>
<td>11</td>
</tr>
<tr>
<td>15 month crop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiji lowlands, dry taro with</td>
<td>19.0</td>
<td>78</td>
<td>12</td>
</tr>
<tr>
<td>fertilizer, 9 month crop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hawaii lowlands, wet taro:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. with fertilizer, 12 month</td>
<td>28.67</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>crop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. P and K fertilizer only</td>
<td>24.08</td>
<td>36</td>
<td>66</td>
</tr>
<tr>
<td>12 month crop</td>
<td>32.49</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>Ontong Java atoll, wet taro,</td>
<td>6.11</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>mulched, 12 month crop</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: Hawaii: A. de la Pena (1970), B. de la Pena and Plucknett (1972); Fiji: Fiji Department of Agriculture (1973); Ontong Java: Field notes.

APPENDIX 5. Food value of taro in human nutrition

<table>
<thead>
<tr>
<th>FOOD</th>
<th>PLACE</th>
<th>SOURCE</th>
<th>ENERGY VALUE PER 100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>kcal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(g/100 g)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw corn</td>
<td>New Guinea</td>
<td>Hipsey and Clements 1947</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>World</td>
<td>FAO 1965</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>South Pacific</td>
<td>Peter 1957</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
<td>Tabb and Cadle 1967</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Africa</td>
<td>FAO 1965</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>Caribbean</td>
<td>Guney 1975</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>South Pacific</td>
<td>South Pacific Health</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Service n.d.</td>
<td></td>
</tr>
<tr>
<td>Boiled corn</td>
<td>American</td>
<td>Marian, Pen and Miller</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Samoa</td>
<td>1958</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Hawaii</td>
<td>Penn 1970</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>San Tome,</td>
<td>Orellana 1974</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baked corn</td>
<td>American</td>
<td>Marian, Pen and Miller</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>Samoa</td>
<td>1958</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>New Guinea</td>
<td>Hipsey and Clements 1947</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
<td>Tabb and Cadle 1967</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>New Guinea</td>
<td>Hipsey and Clements 1947</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>South Pacific</td>
<td>Peter 1953</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Philippines</td>
<td>Tabb and Cadle 1967</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>n.s. - not stated</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes, sources and key to Figures 6 and 5:

a. BHE 1: refers to work inputs in a hypothetical situation of gardens being situated five minutes from the village.

b. BHE 1: refers to actual situation of a 20–30 minute journey to garden land. In both cases the crops are mixed, kava, banana, sugar cane, etc., with taro contributing 30 per cent of total yield. In Figure 5, BHE 4 and BEH 5 are mixed gardens, but in these cases sweet potato predominates. BHE 3 is hypothetically located close to the settlement, whereas BHE 4 is the actual situation, as above (Taguppur 1965, p. 49-52, 293).

c. REL: (Christiansen 1975, p. 65, 95).

d. KAP 1: plots of wet taro. In Figure 5 (sweet potatoes) KAP 2 refers to extensive shifting cultivation. KAP 3 to intensive shifting cultivation, and KAP 4 to perennial cultivation (Prentice 1963, p. 423, 436-444). BAE in Figure 5 refers to intensive and mixed perennial cultivation of sweet potato by the Kalypa Enga of the Central Highlands of New Guinea (Davidd 1972, p. 119, 199; Morrow 1977, p. 269).

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APPENDIX 6. Data on taro cultivation in Pacific societies

<table>
<thead>
<tr>
<th>SOCIETY, LOCATION, POPULATION</th>
<th>LAND PLANTED WITH Taro (ha)</th>
<th>YIELD PRODUCED (100 kcal/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL CULTIVATED (hours/yr)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Tewakapu Honig, Dianar Mts., New Guinea (pop. 204)</td>
<td>27.46 (612)</td>
<td>19070</td>
</tr>
<tr>
<td>b. Ditto</td>
<td>27.62 (612)</td>
<td>25530</td>
</tr>
<tr>
<td>c. Bollons Island, Solomon Islands, (pop. 271)</td>
<td>13.1 (23)</td>
<td>20100</td>
</tr>
<tr>
<td>d. Bedwali, Yapen, West Irian (pop. 2181)</td>
<td>0.20 (23)</td>
<td>470</td>
</tr>
<tr>
<td>e. Bongolong-Angking, Niasina Mts., New Guinea (pop. 154)</td>
<td>14.57 (n.s.)</td>
<td>31990</td>
</tr>
<tr>
<td>f. Taveuni Island, Fiji (canoe per hectare)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>g. Menaqasea, Lakeba, Fiji (pop. 271)</td>
<td>3.99 (n.s.)</td>
<td>29990</td>
</tr>
<tr>
<td>h. Siewa, Popondetta, New Guinea (pop. 437)</td>
<td>5.03 (91c)</td>
<td>32280</td>
</tr>
<tr>
<td>i. Dufat, Western Samoa (pop. 286)</td>
<td>5.26 (30E)</td>
<td>25350</td>
</tr>
<tr>
<td>j. Ditto</td>
<td>5.26 (30E)</td>
<td>38000</td>
</tr>
<tr>
<td>k. Ontong Java, Solomon Islands (pop. 850)</td>
<td>3.30 (68)</td>
<td>51300</td>
</tr>
</tbody>
</table>

91
Modelling the Taveuni island economy: a preliminary study

J.B. Hardaker
Department of Agricultural Economics
University of New England
Armidale, New South Wales
Australia

An understanding of the relationships between the technical, demographic and economic variables of an island economy is important to planners and policy makers. This study represents an attempt to develop a simple operational model of the economy of the island of Taveuni in Fiji for the purpose of studying these relationships. The analysis is preliminary in the sense that it is based on a less than wholly adequate data base. Although the present modelling exercise was envisaged at a very early stage in project planning, subsequent events dictated that the writer could not become involved in the field until after most of the data had been collected, so that data were not gathered with his requirements primarily in mind.

Partly for this reason, and partly because of the difficulties inherent in observing and measuring many of the relevant variables and relationships, it has not been possible to construct a model of the economy of Taveuni which is as detailed and comprehensive as might be desirable for elucidating policy issues. In particular, no validation of the model has been attempted, so that it is not possible to say how well, or how badly, the model mirrors selected features of reality. Mainly for this reason, the results outlined on the following pages must be regarded as very tentative. Little confidence can be attached to the exact magnitudes of variables, such as incomes per head, obtained as outputs of the model. On the other hand, provided that the structure of the model is a reasonable caricature of the real system, the results obtained should be illustrative of the form of relationships to be expected of the real system. Hence, provided they are interpreted with discretion and a good understanding of the reality of the Taveuni economy, the results may provide useful insights into some of the policy issues to be faced in that island.

THE MODEL

THE MODELLING APPROACH

Linear programming modelling

The approach to analysis of the Taveuni economy adopted in this study is based on an aggregated linear programming model. Linear programming is an optimising procedure in which a linear objective function is maximised (or minimised) subject to a set of linear constraints. The model is aggregated in the sense that individual production units (agricultural holdings) and consumption units (households) are not represented. Instead, these production and consumption units are combined together to form 'sectors' within the model, as discussed below.

The linear assumption of the linear programming framework has the advantage of reducing data needs in comparison with more general non-linear models, albeit at the cost of some loss of realism. This assumption implies, for example, that constant returns to scale prevail in production. While this assumption is unlikely to be strictly valid, the extent of departures from constant returns to scale is unlikely to be great for the types of agriculture practised in Taveuni. However, the limitations of the model, including the limitations arising from the assumption of linearity, are considered further below.

An important advantage of the adoption of a linear programming model compared, among other possible methods available such as a
Modelling the Toaenu island economy

The model formulated

Four sectors

The model of the economic system of Toaenu island is based on prices and other conditions prevailing in 1975. The model incorporates a division of the island economy into four sectors. These are: villages; settlements; estate production; and estate households.

The village sector includes the production and consumption of native Fijians living in villages. Similarly, the settlement sector incorporates production and consumption of both native Fijians and Indo-Fijians living on land settlement schemes.

The estate production sector relates solely to commercial crop production on estates, while the estate household sector represents the labour supply available from, and consumption by, all those estate workers not included in villages or settlements. Some limited production activities by estate workers on their own land are also represented.

Within each sector activities representing production are confined to the main crop activities, other forms of production being excluded from consideration. Similarly, food consumption by household is considered only in terms of crop products, although it is assumed that there is a minimum level of cash expenditure on "other" goods and services.

The village sector as example

The structure of the model can be illustrated by considering one sector. The submatrix representing the village sector is shown in Table 1. The activities and constraints of this submatrix are almost the same as those for both the settlement and the estate household sectors, although the coefficients in the submatrices for these other sectors are generally not the same as those in the table. The estate production sector is represented in a quite different way, as discussed below.

Village production and consumption activities are represented by the columns of the submatrix in Table 1. Column 4 to 6 in the table represent the production of cash crops; the crops included being coconuts (including copra manufacture), taro and yampons. Taro cash cropping is differentiated into production for export to the National Marketing Authority (NMA) in Suva, and production for local sale to other sectors. Columns 7 to 7 represent production of crops for domestic consumption within the sector. The crops included are taro, cassava and coconuts. Columns 8 and 9 represent respectively opportunities for hiring labour from other sectors, and for "selling" labour to other sectors. One or other of these activities may be set at a non-zero level according as the village sector has a sufficient excess of labour. Finally, Column 10 provides for the purchase of food from other sectors, should this prove necessary or worthwhile.

The rows of the submatrix in Table 1 represent the constraints on production and consumption within the village sector. The right-hand side column shows the level of each constraint. Row 1 relates to the supply and consumption of labour within the sector. Thus, to illustrate the form of the constraints, the right-hand side value for this row shows that 15,733.4 man days of labour are estimated to be available per annum. The entries in this row under the crop activities show the labour requirements per unit level of each of those activities. Similar interpretations apply to subsequent rows.

The purpose of this constraint is to ensure that the households included in the village sector are able to generate a positive cash income. It should be noted that, in consequence of the aggregated nature of the model, no account is taken of the distribution of cash income amongst households within the sector. In a similar fashion, row 3 represents the aggregate minimum food needs, in gigajoules per annum, of the households in the village sector.

The constraint in the fourth row of Table 1 imposes a limit on the total area of field crops. This limit is set to represent the arable area estimated to be currently (1975) used for field crop production within the sector. This constraint is supplemented by the constraint in row 11 which restricts yampon production to one third of one cent of the arable area. This limit was subjectively chosen to prevent the selection of land-use programmes having a very low yampon content. Row 5 represents a constraint included in recognition of the essentially subsistence nature of the economy of this village sector of Toaenu. It was considered unrealistic to permit solutions in which a very high proportion of the food requirements of the sector were purchased. For this reason, food purchases are restricted to a maximum of 40 per cent of the estimated total needs of the sector for food energy. The upper limit of food purchases was released for the estate households' sector where greater reliance of purchased food is customary.

The constraint in row 6 specifies the total quantity of coconuts available within the sector for manufacturing into copra or for consumption. The figures given in rows 7 to 10 of the submatrix, represent restrictions on dietary composition within the sector. These constraints are included to reflect the customary eating habits of the people and to ensure some minimal diversity of diet. Thus, upper limits are imposed on the amount of food energy which can be provided by coconuts, by taro, or by cassava, and a minimum level of consumption of taro is also specified, in recognition of the prime place this foodstuff holds in the diets of native Fijian villagers in Toaenu.

The estate production sector. The submatrix for the estate production sector is much simpler than that shown in Table 1, since no field crop activities and no consumption of foodstuffs are represented, the two activities specify commercial copra production at different levels of intensity, while a third activity stipulates that labour is to be hired from other sectors (ordinarily from the estate households sector).

The model as a whole

The submatrices for the four sectors are combined into a single matrix in block-diagonal form, as illustrated in Figure 1. In addition, as indicated in the figure, some general constraints, applying across all sectors, are included. First, a constraint is specified to tie the levels of production of taro for local sale to the purchases of food. In a similar way, a second constraint ties the amount of labour 'sold' to the total amount hired. Finally, one constraint is included to restrict total production of taro for export to the export quota set by the NMA.

The objective function. The model is completed by specification of an objective function, i.e., the objective of the joint solution of the model is to maximise the total net revenue over all sectors. For this purpose, net revenue is defined as income minus expenses.
measured for cash transactions only. However, it should be emphasised that the model already includes constraints guaranteeing an adequate level of nutrition in every sector. In other words, the objective function represents the value added by the Tavuni Island economy, over and above the value of subsistence production.

Characterisation of model

In all, the model described above consists of 39 constraints and 33 activities. A list of the matrix for the basic model is attached as Appendix I. A number of features of the model developed deserve special comment. First, it should be noted that all prices in the model are exogenously determined. This is true not only for exports from and imports to the island economy, but also for the prices of the two commodities, food and labour, that are traded between sectors. It would have been desirable to have determined the prices of these two commodities endogenously. However, this is not practicable within the linear programming framework, and in any case, relevant data on elasticities were not available.

A second feature of the model that warrants comment arises from the conditionally normative nature of the linear programming approach. Within the limitations of the analysis, the solutions generated would be optimal for the Tavuni Island economy. In the sense that they lead to maximum total net revenue, as defined above. However, it is not to be deduced that these necessarily are forces at work in the economy that would guarantee that the optimal resource allocations would occur; rather the solutions indicate what would be possible, within the constraints specified, if appropriate policies of economic management were adopted.

A third feature of the model of importance is the embedded assumption of non-transferability of land-based resources between sectors. While in the short run this assumption is quite realistic, in the longer run it may be that changes in land tenure policy could lead to substantial transfer of land between sectors. As described below, the model was subsequently modified to explore the consequences of such a transfer.

Finally, it should be noted that, with the exception of estate copra production, only production technology for each crop is represented in the model. The model has been used to examine the consequence of substantial shifts in relative resource endowments. It would, of course, be reasonable to expect that for example, a substantial increase in population would be accompanied by a change to more intensive methods of agricultural production (Roscrup 1965). Unfortunately, sufficient data were not available to define alternative technologies for field crop production and the results described below should be interpreted with this limitation in mind. In the case of estate copra production, the dramatic fall in copra prices during 1974 and early 1975 provoked changes in the methods of production employed. In consequence, sufficient data were obtained to permit two levels of production, involving different levels of intensity of labour use, to be defined in the model.

RESULTS FOR THE BASIC MODEL

The solution obtained for the basic model indicates a total net revenue for the whole island economy of just under $5.0 million. This corresponds to a mean annual income per head of $635. In interpreting these figures it should be noted that net revenue includes the value of all produce sold from the island, but excludes the value of transfer payments between sectors, such as sales of food and payment of wages. As noted previously, no account is taken of the distribution of income, except for the inclusion of constraints to impose a minimum cash income per head in each sector.

The income reported above is earned from three sources; copra, yaqona and taro exports. In all, 563 t of copra are produced, allocated between sectors as:

- villages: 177 t
- settlements: 391 t
- estate production: 10 t

Only in the estate households sector is a proportion of the available coconuts devoted to domestic consumption. The pattern of field crop production in the optimal solution is shown in Table 2.

VARIANTS IN THE BASIC MODEL

Two variants of the basic model have been analysed. First, the implications of a halving in the price assumed for yaqona are studied. The price prevailing in 1975 was particularly high in comparison with earlier periods. Thus it was considered quite possible that a substantial fall in yaqona price could subsequently occur, especially since the high prices prevailing would be likely to lead to increased planting, both in Tavuni and in other islands. As already noted, the optimal solution...
for the basic model indicates heavy reliance on yagona production.

In attempting to evaluate the model that was considered incorporated a substantial increase in the export quota for tare. It was considered that, with improvement in the growing arrangements, it should be possible to sell much more tare to Suva and elsewhere. The effect of increasing the limit on tare exports from 400 t to 2000 t was therefore examined.

Halving the yagona price led to a reduction in total net revenue of some $3.2 million to just under $1.8 million. This corresponds to a decline in net revenue per head from $635 to $406, a fall of 35 per cent. Apart from this decline in income, no change in the optimal solution is associated with the decline in yagona prices. In fact, as implied above, the resources devoted to yagona production in the village and settlement sectors have zero opportunity costs, so that the yagona production activities in these sectors would remain in the solution as long as they generated a positive net revenue.

In contrast, an increase in the tare export quota from 400 t to 2000 t does produce a change in the optimal activity mix. The new pattern of land use is shown in Table 3. In comparing the figures in Table 3 with those in Table 2 for the basic model, it can be seen that practically the only difference is a change in the area of tare grown in the village and settlement sectors. The whole of the extra tare produced is, of course, exported.

Table 3. Land use, basic model with increased tare quotas

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>VILLAGE</th>
<th>SETTLEMENTS</th>
<th>ESTATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha</td>
<td>ha</td>
<td>ha</td>
</tr>
<tr>
<td>Yagona</td>
<td>518.0</td>
<td>526.5</td>
<td>41.9</td>
</tr>
<tr>
<td>Tare</td>
<td>150.7</td>
<td>61.3</td>
<td></td>
</tr>
<tr>
<td>Cashews</td>
<td>731.7</td>
<td>65.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Unused</td>
<td>55.4</td>
<td>156.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>797.0</td>
<td>840.0</td>
<td>67.2</td>
</tr>
</tbody>
</table>

The effect on total net revenue of the five-fold increase in the tare export quota is minimal. Total revenue, and hence income per head, both increased by 3 per cent, corresponding to an improvement in income per head of just under $21. Since the

scope for an expansion of tare exports of the order considered, is to say the least, problematical, this result seems to indicate that it would be unrealistic to place much reliance on the expansion of tare production as a basis for future development of the Tavua economy.

EFFECTS OF INCREASES IN LAND AVAILABLE FOR FIELD CROPS

The model solutions discussed thus far have been based on a restriction of field crops to the estimated land area currently under cultivation in the various sectors. Moreover, as already explained, it has also been assumed that not more than 65 per cent of this cropped area is suitable for yagona growing. In fact, the potential arable area of the island is much greater than the area currently under cultivation. The difference between the present and the potential extent of cultivation can be largely explained in terms of institutional factors, such as the relatively rigid land tenure arrangements.

In order to elucidate the possible consequences of land use practices that might bring more land into cultivation, parametric programming has been employed. The effect of increasing the limit on yagona in the village and settlement sectors has been varied upwards from the present level to 300 per cent of these levels. The parametric programming procedure employed for this purpose provides information on all changes of basis solutions within the range of interest.

The effect of parametric increases in the field crop area on total net revenue is illustrated in Figure 2. The figure shows results for both the basic model and for the model in which yagona prices were assumed to be halved. The figure shows total net revenue for both models increases with increase in the field crop area, although there is some decline in the rate of increase as the area is expanded beyond about 200 per cent of the present level. Moreover, it may be seen that a three-fold increase in the cropped area for the basic model leads to an increase in total net revenue from approximately $15.6 million to over $10.5 million.

As might be anticipated from the foregoing discussion, this expansion in income is associated with a substantial increase in yagona production. Initially, this increase is followed by a decrease in the levels of the other production activities, but, as labour becomes scarce, adjustments in the levels of labour begins to rise. The stepped nature of the curve shown in Figure 3 arises in consequence of the linear assumptions adopted in formulating the model. In reality we might expect a rather smoother curve. Nevertheless, the figure shows that the NVP of labour rises very sharply once labour becomes limiting, and quickly passes the institutional wage rate of about $4 per day. The NVP levels off at about $6 per day for a two-fold increase in field crop area, but at the same area is expanded beyond 250 per cent of the present level, further increases in the NVP of labour occur. At the limit of area expansion considered, the NVP for the basic model reaches $14 per day. Figure 3 also shows that reduction in yagona has no effect on the NVP of labour, except when the field crop area approaches 300 per cent of its present level.

REVISION OF THE MODEL

As part of the Unesco/UNFPA Project in Fiji, the land resources of Taveuni were classified, mapped and measured (Unesco/UNFPA 1977 p. 69). Using these data it was possible to estimate the potential arable area in each sector. With this information, a revised version of the model was constructed that could be regarded as representing an upper bound to the opportunities for expansion of field crop production within the present structural and tenurial arrangements. This model incorporates a 265 per cent increase in the arable area in the village sector and a 236 per cent increase in the settlement sector. Land area available to estate households (NWP) of labour begins to rise. The stepped nature of the curve shown in Figure 3 arises in consequence of the linear assumptions adopted in formulating the model. In reality we might expect a rather smoother curve. Nevertheless, the figure shows that the NVP of labour rises very sharply once labour becomes limiting, and quickly passes the institutional wage rate of about $4 per day. The NVP levels off at about $6 per day for a two-fold increase in field crop area, but at the same area is expanded beyond 250 per cent of the present level, further increases in the NVP of labour occur. At the limit of area expansion considered, the NVP for the basic model reaches $14 per day. Figure 3 also shows that reduction in yagona has no effect on the NVP of labour, except when the field crop area approaches 300 per cent of its present level.
was assumed to remain unchanged and nor were any opportunities included for diversification of production on estates. The model including these expanded arable areas is hereinafter referred to as the 'revised model'.

The revised model and the market for yqona

The solution obtained for the revised model with high yqona prices follows the pattern already established by the results for the basic model with parametric increase in land area. Total net revenue for the revised model is $10.7 million, or $1367 per head. This is more than double the income generated in the solution to the basic model. The extra income is earned from increased yqona production. The labour requirements for this crop are not heavy that no copra at all is produced. The pattern of land use in the optimal solution, showing the predominance of yqona, is indicated in Table 4.

The plausibility of an agricultural economy for Taveuni based on such heavy reliance on a single product is obviously dubious. The market for yqona is almost wholly a domestic market within Fiji, and little is known about the nature of the demand for this product. However, the fact that a recent shortage of yqona provoked a dramatic increase in price, coupled with the nature of the product itself, may be taken as strong evidence of a very inelastic demand. A sharp increase in production of the magnitude indicated in the solution to the revised model could well cause prices to plummet. Whilst it is possible that yqona could find an export market for manufacture into certain pharmaceutical products, this outlet is yet to be developed in Fiji. Consequently, the

Table 4. Land use, revised model

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>VILLAGES</th>
<th>SETTLEMENTS</th>
<th>ESTATE</th>
<th>HOUSEHOLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1250.5</td>
<td>1340.1</td>
<td></td>
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<td>92.7</td>
<td>58.5</td>
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<td>30.5</td>
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<td>896.3</td>
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</tr>
<tr>
<td>2913.8</td>
<td>2718.0</td>
<td>67.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Effects of parametric increase in land area for field crops on marginal value product of labour

Figure 4. Effect of parametric increase in population on total net revenue

Figure 5. Effect of parametric increase in population on net revenue per head
solution indicated for the revised model cannot confidently be regarded as representing a realistic possibility. Rather it should be taken as indicating the consider-
able potential of Tavenu for agricultural production if some existing constraints could be broken and a suitable cash crop found.

POPULATION GROWTH AND THE REVISED MODEL

The effects of population growth on the economy of the island have been investigated using the revised model. All population-related co-efficients in the right-hand side columns of the matrix for the revised model were varied parametrically to represent growth of population above the present level. All other features of the model, including the production technologies assumed to be available, were held constant. The results of this analysis for the revised model, and for the same model with a halving of the yqona price, are summarized in terms of total net revenue and net revenue per head in Figures 4 and 5 respectively.

Figure 4 shows that, for both cases considered, the initial effect of population growth is to increase total income. However, diminishing returns quickly set in and, for both levels of yqona price, total net revenue reaches a maximum for a population one and a half times the present level. Subsequent increases in numbers bring about a small but steady decline in total net revenue until a population level about 265 per cent of the present level is reached. At this level, further population growth is inconsistent with the constraints specified on minimal standards of cash income and nutrition, and no further solutions to the model exist.

Figure 4 shows the effects of increased numbers on net revenue per head of population. An increase of up to about 15 per cent at the high yqona price, and up to about 20 per cent at the low price can be accommodated with no reduction in income per head. Thereafter, population growth brings about a steady fall in average income.

Labour productivity in the island economy naturally tends to decline as the population increases relative to the fixed land resources. This decline, as measured by the MFP of labour, is shown in Figure 5. Starting from Initial levels of productivity that are several times the current wage rates, the MFP of labour falls sharply with population growth. As population increases approach 50 per cent, the MFP of labour first falls below the wage rate and then quickly drops to zero, indicating a labour surplus at some point.

The above parametric analysis indicates 'milestones' on the continuum of population growth. First, an outflow of 14 to 20 per cent (depending on the yqona price) can be accommodated with no decline in net revenue per head, since total net revenue increases in proportion to population. Second, a 50 per cent population increase brings about a labour surplus situation and in this sense represents a limit on the capacity of the economy to provide productive employment. Total net revenue is a maximum for this level of population, although net revenue per head is considerably less than the level for no-growth position. Finally, an upper limit on the physical carrying capacity of the island, as defined by the constraints, occurs when population is some 265 times the present level. Of course, in reality the island might well be able to support a larger population than this since the minimum standards adopted are well above the threshold for survival. Moreover, the stresses imposed could be expected to provoke changes in the employed (Rose-rup 1965) and in the institutional structure.

EFFECTS OF A LAND REFORM

In both the basic and the revised models analyzed above, the present division of land between sectors has been assumed to be rigid. Moreover, it has been assumed that the arable land in the estate production sector can be utilized only for copra production. A number of observations suggest that such rigidity might not be a valid assumption in the longer run. Growth of population in the island is likely to create increasing hardship amongst families with little or no access to land, notably those in the estate households sector. The social and political consequences of such changes could well make land reform a political necessity. Secondly, under prevailing prices and costs, commercial copra production is of marginal profitability (Brookfield 1976). The productivity per hectare of many of the estates in Tavenui is low and is declining as the palms age. This trend is likely to continue unless there is a period of high copra prices that is sufficiently sustained to encourage owners to invest in plantation rehabilitation and replanting programs. In the absence of such an unlikely turn-about in the economic fortunes of the copra estates, it seems likely that owners will seek to change terms of production, or will seek to encash their investments by selling up or by leasing portions of their land to cash farmers who would use it for field crop production.

A model incorporating land redistribution

To investigate the potential for increased production in Tavenui arising from a redistribution of the estate lands, a third programming model was developed. In this model the production sector is eliminated and the land resources (including the coconuts produced from that land) are allocated to the settlement sector. It is further assumed that the estate households, which presently constitute the main source of labour for commercial copra production, would join the settlement sector. Thus this model contains only two sectors: a village sector, which is unchanged from the previous model, and a greatly enlarged settlement sector. The field crop area assumed to be available in the model is the initial arable area as defined for the revised model, although, of course, now including the arable land previously in the estate sector. The effect of parametric increase in population on this two-sector model is also investigated.

The results for the two-sector model for the present level of population are virtually identical to those for the revised model. Total net revenue, and hence revenue per head are both unchanged from the levels achieved in the revised model. The net revenue per hectare of land use is identical, except that, as might be expected, the division of crops between sectors is changed.

The reason for the similarity in the results for the two models is that the limiting factors in the revised model are labour and market constraints. In the two-sector model there is no change in the overall supply of labour and nor are marketing opportunities expanded. Thus, the increased area available for arable cropping remains unused.

The difference between the revised model and the two-sector model becomes apparent as the level of population is increased. In the revised model, at the high yqona price, an increase in population of only 14 per cent was possible without a decline in net revenue per hectare. In the two-sector model, population can be increased to more
than three times its present level before any decline in income per head becomes evident. In the revised model, an upper limit on population increase was found to exist at about 200,000 per cent of the present level. In the two-sector model, it was found that population could increase more than thirty times to over 200,000 before a similar insensitivity was encountered. It is, of course, not sensible to contemplate such a massive increase in population in relation to a model in which technology and prices are assumed to remain constant. Rather this result should be interpreted as indicating the enormous expansion in the capacity of the land of Taveuni to support people if the rigidities and inequities of the present land tenure system could be overcome.

**OVERVIEW AND CONCLUSIONS**

As noted in the introduction, this modelling study of the economy of Taveuni Island has many limitations, in terms of both the form of the model employed and the data base available. Nevertheless, the general patterns of the results obtained conform well with a common sense interpretation of circumstances affecting the level and patterns of economic activity in the area.

The results described above emphasise the importance of existing constraints on agricultural production in Taveuni. The limited export market for taro, and more importantly, the absence of a proved alternative cash crop to yam, emerged as important issues. The opportunities to raise average incomes by bringing more arable land into cash crop production were demonstrated by a number of the analyses. However, in all cases, this increased income was earned predominantly by expansion in yam cropping. Yam was found to be so much more profitable than copra production that, as the opportunity for increased cultivation of yam was provided, labour was progressively transferred out of copra production to the point where little or no copra was produced. The vulnerability of an economy with projected heavy reliance on a crop such as yam, with its very limited and rather uncertain market, is obvious. The capacity of the island to support people was explored using two models. It was shown that, by bringing more arable land into cultivation, increased numbers of people could be supported with no decline in incomes per head. On the other hand, there was no gain in per capita income from increasing population. The range over which this constant level of income was found to prevail as population increase was accounted for in the models depended crucially upon the assumptions made about accessibility of the arable land resources of the island. However, in both cases investigated, a point was reached at which incomes per head began to decline as population grew. This point occurred before the point of labour surplus was reached, at which population level total net revenue was at a maximum. Further growth in population caused a decline in total net revenue as well as in net revenue per head. Eventually, in both analyses, levels of population were reached at which insolvency was encountered, and no further population growth could be sustained within the constraints and assumptions adopted in the models. These levels of maximum population were substantially greater than the present level, so that the prospects of a looming Malthusian cataclysm can be dismissed. Changes in production methods would invalidate the model results long before this upper population bounds are approached.

The overriding impression gained from this modelling study is of a rural economy with considerable untapped potential. Labour and land are both abundantly available in the present Taveuni economy. The challenge to planners and policy makers, and to agricultural research and extension workers, is to find the means whereby this potential can be tapped to improve the standard of living of the people of the island and of the nation as a whole.
Modelling the Tuamotu island economy

BIBLIOGRAPHY


The study of land potential: an open-ended inquiry

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Centre ORSTOM
Noumea
New Caledonia

In the initial design of the Unesco/UNEP Project in Fiji, one of the stated objectives was a scientific description of the agroecological qualities of the land resources, together with an estimate of their capacity to withstand and support cultivation. Added to this was an emphasis on the dynamics of change in the soil-vegetation complex, viewed as the expression of interaction between variable environmental conditions and the impact of changing human occupancy. Following the conclusion of a mutually welcomed agreement between Unesco and ORSTOM, and approval of this agreement by the Government of Fiji, the present authors were charged with primary responsibility for this task, in collaboration with other members directly recruited by the project. Field work was carried out on five islands (Lakaba, Taumai, Haurini, Batiki and Kahara) among which four were also studied from other points of view. In terms of their ecology, some of these islands was previously well-described. The major source of the soil and vegetation of Fiji (Twyford and Wright 1965) is concerned principally with the two main islands - Viti Levu and Vanua Levu - and discussion of the smaller islands is based only on reconnaissance. The islands chosen for study in the present project were selected on the basis of their representativeness in terms of the range of ecological conditions encountered in the eastern part of Fiji. Moreover, all had been heavily affected by human occupation, and hence were particularly appropriate for study in a pilot project within the Man and the Biosphere Programme of Unesco. On present evidence, it would appear that these islands were first populated by man about 3000 years ago. Such occupation is presumed to have initiated a range of environmental transformations, by clearing of the forest and use of fire.

The 'talasiga' formation - the most extreme of a range of pyrophytic formations supported by very degraded soils - was either formed or greatly enlarged as a result of this interference. Soil erosion, and the creation of large areas of colluvium, may also be presumed to have arisen from, or been accelerated by, the interference of man with natural environmental processes.

In so far as the team was concerned with evaluating the suitability of land for agricultural use, which was its pragmatic objective, the context had to be a search for the optimal production capacity of these environments, consistent with preservation or amendment of ecosystems that are already in a very unstable condition. It was decided to base the work on the task of classification using the 'system for evaluation of soils' proposed by FAO (1976). Three stages of work are therefore involved:

- definition of ecological units;
- evaluation of the agroecological qualities of land;
- evaluation of land-use potential, taking account of the consequences which any particular form of use might have on the environment.

1Based on work still in progress at the University of Auckland, and by this project.

2In Fiji, the term 'talasiga' means 'sun-burnt land' (Latham 1972). The term designates both a pyrophytic vegetation complex dominated by ferns, often in association with Casuarina equisetifolia, and also the very degraded and often eroded soils which support the complex. It is used in what follows as a generic term for a soil-vegetation complex which, while not limited to the eastern islands of Fiji, is particularly well exemplified on some of these islands, outstandingly Lakaba.

The emphasis given to each of these stages varied according to the practical possibilities of access to islands, to knowledge of the environmental conditions as a whole, and to the purposes of the project, which was designed as a pilot study in this area. The approach adopted is represented diagramatically in Figure 1.

Figure 1. Flow chart representing the method employed for the study of land potential

I. THE DEFINITION OF ECOCALOGICAL UNITS

The term 'ecological unit' is a compromise between the 'land unit' of most land-evaluation studies and the 'ecosystem' favoured by the Man and the Biosphere Programme. Many of the ecological units would in fact be congruent with natural ecosystems, being land units of relatively uniform environmental conditions capable of separate analysis in terms of their life-support systems, but to an extent of ecosystems involves questions of bonding and the import and export of energy and matter, which are not faced in this work. For an essentially reconnaissance study, the term 'ecological unit' seems more appropriate. Even so, the task of defining such units demands a large input of new research, since these island environments are little-known scientifically, in view of their isolation and small size. Moreover, the environments of the different islands are very varied, and many elements are unique to particular islands. Within-island variation is often as marked as between-island variation. A short description of each island will introduce the discussion which follows. That discussion is based primarily on Lakeba, the most complex of the islands studied from an ecological viewpoint, but draws also on conditions elsewhere in the archipelago.

LAKEBA

Although only 56 km² in area, Lakeba is an island of quite unusual ecological complexity. Basically, the island constitutes an andesitic maars of Miocene age, partly covered by Pliocene limosites, of which only fragments remain. In the present era, it experiences an oceanic tropical climate, with a mean rainfall at coastal sites of around 2000 mm yr⁻¹. A succession of somewhat different palaeoclimates, together with general uplift, has led to the formation of a range of morphological units, including basaltic plateau areas, eroded hills, large colluvial zones in the valleys and lowlands, and alluvial coastal plains within which are quite numerous valley and sub-coastal swamps. A wide range of soils has evolved in these morphological units, among which the most naturally developed are the 'talisaga' soils (acic ferralsols and ferralsols cambisols), while the least mature are the soils of the plains (eutric fluvisols, rendzinas, histosols and humic gleysols). Great diversity of vegetation is associated with these soil-landscape complexes: dense forest, red thicket, forest vegetation dominated by farns (talisaga vegetation), and hydromorphic herbaceous vegetation. Notwithstanding its small size, the range of ecological units encountered in Lakeba exceeds the range encountered on any of the other islands visited.

KABARA

Kabara is representative of a group of uplifted steams, and occupies 52 km². In the northwest, however, is an outcrop of basalt of Pleistocene age. Three principal environments may be distinguished. Most of the island is formed of a limestone basin, sloping inward from the encircling ridge toward the centre, and containing some pockets of basaltic soils (humic ferralsols); this whole area is covered in dense forest. Second is the small volcanic hill which carries the principal cultivated area, but where soils (acic cambisols) are badly eroded. Third are the coastal plain areas of sand or renderas, which are mainly under coconut. Kabara's environment is therefore quite simple, but very different from that of the other islands.

TAVUNUI

Tavuni is much the largest of the islands studied (264 km²), and is not representative of any other island but itself. Geologically, it is the most recent in formation. Major eruptions have taken place within the past 3000 years, concluding perhaps within the past 1500 years, and the whole volcanic mass is of upper Pleistocene and Holocene age. The climate is unusually humid, mean annual rainfall exceeding 6000 mm in parts of the island. According to the age of the volcanic parent material, soils may be divided into an andic group and a ferralsic group with basaltic tendencies. Except where cleared for coconut or other cultivation, a dense forest covers the whole island to the summits. Tavuni is a young island, of fertile volcanic soils characterized by a dense rain forest with little or no evidence of degradation.

SUMMARY

The environments of these islands are varied, and contain distinctive elements. Because of its diversity, work on Lakeba alone occupied half the time allotted to the ecological survey in the field. Maps have been prepared for Lakeba at a scale of 1:25,000 and of parts of Tavuni at 1:50,000; sketch maps only were prepared for Kabara, Nairai and Betiki, at the 1:50,000 scale. Table 1 summarizes the main environmental characteristics of each island.

The three essential elements in the definition of ecological units are inquiries into geomorphology, soil science and the nature of the biota. They are all indispensable to an un-
standing of environment, its natural fertility and its productivity. For each island, problems of classification, but especially of soils and vegetation. In order to facilitate international comparison, the FAO/UNESCO (1972) system was used for classification of soils, and the Unesco (1973) system for vegetation.

### Table 1. Ecological characteristics of the islands studied

<table>
<thead>
<tr>
<th>ISLAND</th>
<th>AREA (km²)</th>
<th>GEOL OGY</th>
<th>TOPOGRAPHY</th>
<th>VEGETATION</th>
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<tr>
<td>LARKA</td>
<td>56</td>
<td>Ancestral (Micocene)</td>
<td>Eroded slopes</td>
<td>Acric ferralsols&lt;br&gt;Humic and chroic ferralsols&lt;br&gt;Chromic cambisols&lt;br&gt;Grayic cambisols&lt;br&gt;Fluvisols&lt;br&gt;Bendals and&lt;br&gt;Lithosols&lt;br&gt;Chromic cambisols&lt;br&gt;Ferralsols&lt;br&gt;Humic ferralsols&lt;br&gt;Lithosols&lt;br&gt;Forest and forest vegetation&lt;br&gt;Forest and forest vegetation&lt;br&gt;Forest vegetation&lt;br&gt;Forest vegetation&lt;br&gt;Freshwater vegetation&lt;br&gt;Coconuts and food crops&lt;br&gt;Coconuts and food crops&lt;br&gt;Coconuts and food crops&lt;br&gt;Coconut and food crops&lt;br&gt;Freshwater vegetation&lt;br&gt;Freshwater vegetation</td>
</tr>
<tr>
<td>LAMAL</td>
<td>28</td>
<td>Basalt (Pliocene)</td>
<td>Eroded slopes</td>
<td>Humic ferralsols&lt;br&gt;Ferralsols&lt;br&gt;Chromic cambisols&lt;br&gt;Grayic cambisols&lt;br&gt;Gleysols and&lt;br&gt;Lithosols&lt;br&gt;Scrub with weeds&lt;br&gt;Scrub with weeds&lt;br&gt;Scrub with weeds&lt;br&gt;Scrub with weeds&lt;br&gt;Scrub with weeds&lt;br&gt;Coconuts and cultivation</td>
</tr>
<tr>
<td>TAIKE</td>
<td>9</td>
<td>Basalt (Pliocene)</td>
<td>Eroded slopes</td>
<td>Humic ferralsols&lt;br&gt;Chromic cambisols&lt;br&gt;Ferralsols&lt;br&gt;Bendals and&lt;br&gt;Lithosols&lt;br&gt;Forest vegetation&lt;br&gt;Forest vegetation&lt;br&gt;Forest vegetation&lt;br&gt;Coconut and cultivation</td>
</tr>
</tbody>
</table>
| KABAR | 52 | Basalt (Pleistocene) | Coastal plains | Humic ferralsols<br>Lithosols<br>Coconuts and low-angle flows<br>Ferralsols<br>Chromic cambisols<br>Bendals and<br>Lithosols<br>Forest vegetation<br>Freshwater vegetation<br>Freshwater vegetation<br>Freshwater vegetation<br>Freshwater vegetation

### II. EVALUATION OF THE AGROLOGICAL CHARACTERISTICS OF ECOLOGICAL UNITS

Having defined the ecological units, the next step in an applied study such as the present is to determine more precisely their agrological characteristics. Study of three principal elements is involved:

- the edaphic constraints of the soil;
- the constraints of morphodynamic processes;
- the possibilities of rational management.

### THE EDAPHIC CONSTRAINTS

Without experimentation, or data from experiments in closely comparable conditions elsewhere, approach to the study of these constraints has to follow a process of logical synthesis based on observations. The principal characteristic of the soil being determined, the observation of vegetation and of existing agricultural practice is then compared against these characteristics and evaluated. The biological activity of the soil was also tested, as an important measure of the quality of the soil-plant interface. In these islands, three pedological characteristics were deemed particularly significant in evaluating the edaphic constraints of the soil:

- depth of the natural root zone;
- availability of water to the plants;
- chemical fertility of the soil.

### Depth of the root zone.

This is a basic variable in soil quality. The depth of the natural root zone determines the water and nutrition supplies available to cultivated plants. In these islands, shallow eroded soils are abundant, and this circumstance places strict limitations on the possibility of management. In all soil profiles this variable was observed with particular care.

### Availability of water.

The supply of water to plants is likewise a major determinant of vegetation growth. Even in these relatively humid climates, where annual rainfall generally exceeds 200 cm, water is often a limiting factor of considerable importance. A heavy rainfall occurs during rainy season, and there is a tendency for a dry season, and in the months of the year, and the water stored in the soil. The water reservoir in the soil is thus of major importance in terms of rainwater, and was estimated using the formula developed by Hallaire (1963). Taking account of a mean evapotranspiration of around 100 mm/month, it emerges that water stress can become a serious risk for plant life after only one week without rain across the majority of these islands (Table 2). Mineral deficiencies are notoriously difficult to evaluate in these environments, and their quantitative assessment demands experimental work such as has been carried out in the Cook Islands or the Kingdom of Tonga (Kiddoossen and Blackmore 1975; 1976). It would seem, however, that potassium deficiency is very likely to be a real constraint on the ferralitic soils and the andosols. Moreover, it seems probable that phosphorus assimilation would be a problem on the andosols, following the work in similar locations by Quantz (1973), and Colinet-Dange and Lague (1965).
interesting results were obtained (Table 2), corresponding well with the taxonomic group to which the sample belongs. It emerges that soil fertility in these islands generally exhibits a direct correlation with organic matter content, the plant cover and level of biological activity. In the absence of data which could be extrapolated from other situations, the project relied on these field and laboratory observations in its attempt to define a scale of soil fertility. The morphodynamic constraints

Erosion, sedimentation and the action of the sea all have an important bearing on the question of land capability. Erosion rates were estimated principally from sedimentary deposition in swampy areas, especially on Lakeba; only qualitative observations were possible elsewhere. The rate of sedimentation could be measured through C14 dating of samples obtained at different depths, and erosion rates were then estimated from the area of the upstream catchment. This work was reported in greater detail by N. Latham, F.J. Hughes and M. Brookfield in Brookfield 1979, and also in the final report to be published by ORSTOM. Erosion rates of at least 100-125 t/km²/yr have been estimated both from forested and from talasiga catchments. These rates are high, but are comparable with those calculated from sites elsewhere in the tropics (Trescases 1975; Roose 1975). Rapid erosion may also be observed qualitatively in the field, by the presence of a number of gullies on the hillside and the numerous examples of deposition of weathered andesitic sands on the lower slopes. Material eroded from the slopes is distributed along the valley floors. Carried in suspension in the streams, finer fractions are deposited in the swamps and on flood plains. Other results show that sheet erosion on the slopes and are deposited on land of lesser gradient to increase the depth of the colluvial formations. Some of these deposits are beneficial to soils situated in the lower part of forested catchments, or catchments with other upland soils of high fertility, and it is probably this supply of mineral fertility that explains the high value of the valley swamps of Lakeba, which have been regularly cultivated under taro for many generations. However, colluvial deposits are less often valuable, being largely derived from upland talasiga soils of very low fertility.

The study of land potential

The effect of the sea on the coastal areas is discussed elsewhere in this collection by McLean, and is not further developed here.

Table 2. Comparison between ground cover, soil characteristics of the A horizon and biological activity in Lakeba

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<thead>
<tr>
<th>Ground cover</th>
<th>Tala-siga</th>
<th>Tala-siga Forest</th>
<th>Tala-siga Coastline</th>
<th>Coastline Wetland</th>
<th>Taro</th>
<th>Taro</th>
<th>Taro</th>
<th>Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean cultivated depth (cm)</td>
<td>100</td>
<td>40-60</td>
<td>20-40</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>Hydrophilic 30-40</td>
</tr>
<tr>
<td>Potential water reserve (mm)</td>
<td>80-90</td>
<td>120-140</td>
<td>50-70</td>
<td>120</td>
<td>140-160</td>
<td>(Saturated)</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Physico-chemical characteristics (A horizon):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texture</td>
<td>silty loam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural stability</td>
<td>0.3</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>-</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Bulk density</td>
<td>0.65</td>
<td>0.70</td>
<td>0.87</td>
<td>0.83</td>
<td>0.86</td>
<td>0.52</td>
<td>0.57</td>
<td>0.82</td>
</tr>
<tr>
<td>Porosity</td>
<td>3.0</td>
<td>3.3</td>
<td>3.3</td>
<td>3.7</td>
<td>3.7</td>
<td>3.3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>pH</td>
<td>5.2</td>
<td>6.4</td>
<td>8.0</td>
<td>5.2</td>
<td>6.8</td>
<td>7.1</td>
<td>7.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Exch. Ca (max/100g)</td>
<td>2.6</td>
<td>3.6</td>
<td>9.2</td>
<td>2.6</td>
<td>10.0</td>
<td>14.4</td>
<td>11.4</td>
<td>9.4</td>
</tr>
<tr>
<td>Exch. Mg (max/100g)</td>
<td>0.2</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Carbon exchange capacity (me/100g)</td>
<td>30-70</td>
<td>27.6</td>
<td>27.4</td>
<td>24.6</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Base saturation (per cent)</td>
<td>66</td>
<td>68.9</td>
<td>29.1</td>
<td>66</td>
<td>68.9</td>
<td>29.1</td>
<td>66</td>
<td>68.9</td>
</tr>
<tr>
<td>Phosphorus (per thousand)</td>
<td>1.4</td>
<td>0.2</td>
<td>1.4</td>
<td>2.1</td>
<td>2.4</td>
<td>1.8</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Biological activity in kg of CO2/kg/hour (wet season)</td>
<td>20-40</td>
<td>15-90</td>
<td>35</td>
<td>184</td>
<td>120</td>
<td>260</td>
<td>235</td>
<td>108</td>
</tr>
</tbody>
</table>

The technical possibilities for land management

The constraints discussed above are capable of some reduction by proper management. Such control measures can only be on a modest scale in the short term, given the level of investment for rural development proposed in the current five-year plan for Fiji (Central Planning Office 1975), but a certain minimum level of investment is necessary if an increase in agricultural production is desired. Such investments are possible both in improving the edaphic qualities of the soils and in bringing the morphodynamic processes under control.

Improvement of soil quality. Improvements are possible both in the manner of working the soils, and also in soil enrichment by fertilization. With only limited exceptions, the soils of this region are presently worked manually. Tractor ploughing has been introduced in Tavua, and initiated in Lakeba, and considerable expansion is possible. However, mechanization is significant only in so far as it can contribute to extension of the cultivated area and the introduction of new crops such as cereals, oil seeds, or improved pasture; slope remains a major constraint. The use of manure and fertilizers is certainly capable of more universal expansion. Both mineral fertilization and the use of green manure would permit an increase in yields and also would assist recuperation of infertile soils. Mineral fertilization is presently practised on a very small scale on Tavua and Lakeba, but extension of these practices would demand both a programme of agricultural education, and a large investment.

Very little has thus far been done to manage the morphodynamic processes on these islands. Work is essentially confined to artificially-established drainage on Lakeba, and to erosion control on the volcanic hill in Kabara. Modern drainage in Lakeba is confined mainly to inland valley sites where the slope is greater and depression by livestock less of a problem. Only a few of the formerly drained sub-coastal swamps are still in production. It would seem that to bring the larger of these swamps back into use would now require major works. With the exception of limited patches of wet land on Tavuni, none of which are still in production, and small areas of Naifai and Bati, the problem of drainage and irrigation are presently specific to Lakeba among the islands studied. However, there are much larger areas of swamp on the main islands, some formerly managed and now largely managed, especially in the Rewa delta near Suva.

Erosion, on the other hand, is widespread throughout the eastern island region, yet the only example of effective anti-erosion measures seems to be on Lakeba. On this raised stoll, most of which is concentrated on the slopes and piedmont of the one volcanic hill. This hill has been heavily cultivated for a very long period, leading to severe erosion and truncation of the soil. The upper slopes are now partly circled by contour-line hedges of Gippsornus which check run-off and so reduce erosion. Similar ideas need to be introduced throughout all the other islands of the archipelago, wherever annual food-crop cultivation is carried out. However, this land management is of a very minor order, and needs to be greatly extended in order to permit the better utilization of the soil resources of these islands.
III. DEFINITION OF LAND POTENTIAL

The definition of land potential is an essential basis for rational agricultural planning. In order to be effective, the capabilities of each ecological unit need to be evaluated in terms of the type of agriculture presently employed, or of alternative types which could easily be adopted. It is also necessary to estimate the impact of these land uses on the environment.

Evaluation of land potential

For each ecological unit, there exists a range of possible land uses compatible with the edaphic qualities of the soil and the morphodynamic constraints of the land. Observation of existing cultivation practices provides a useful guide, but there are also other cropping systems found elsewhere in comparable ecological conditions, which are either not practiced, or scarcely at all practised in present-day eastern Fiji. These include cereal cultivation, oil seeds, coffee and oil palm cultivation. Such crops could be established on certain islands to provide more diverse sources of income, but their development would generally require a complete restructuring of the rural landscape and economy. Such remodelling affects principally the dominant position presently occupied by the coconut palm. Estate and smallholder groves of coconuts presently cover much the larger part of the best land on all the islands. At present, however, this area is often old, badly maintained, and of low yield. In cash terms, they offer a low rate of return per hectare, and their presence both inhibits the introduction of more rewarding crops and constitutes a brake slowing down moves toward diversification (UNESCO/UNFA 1977).

The resultant scheme is summarized in Table 3, which shows the land-use systems recognized, cross-classified within each ecological unit by four levels of capability: good, average, mediocre and poor. The object is to permit the planner to make a rational choice among the range of possibilities.

Consequences of land-use systems for the environment

Changes in the system of land use can often, however, lead to very unfavourable secondary effects on fragile natural environments. It has been remarked above that clearing and the use of fire, which followed the arrival of man in these islands, led in some islands to severe degradation. This was especially the case in those areas now occupied by pyrophytic vegetation complexes such as the talasiga and road-thicket. More recent examples include the almost uncontrolled introduction of weeds and plant diseases in the late 19th century, and modern clearance of the forests. No new introduction should ever be proposed without evaluation of its environmental impact, whether by comparison with known cases elsewhere, or by attempts at measurement on site. During the course of the project, three types of land use were examined from this point of view:

- changed in soil under semi-continuous taro cultivation;
- environmental changes under Fimus caribius plantation;
- the effect of shifting cultivation on the environment.

Table 3. An example of land classification for agriculture and forestry: the case of Talasiga.

<table>
<thead>
<tr>
<th>Ecological Units classified by Agroclimatic Quality</th>
<th>Field Crops</th>
<th>Irrigated Crops</th>
<th>Possible Types of Land Use</th>
<th>Improved Grass Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH QUALITY, little erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- alluvial and coastal plains</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>- Eutric Fluvisols, low coconuts</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>- Swamp, Musc Gleysols, low grass fallow and taro</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>MEDIUM QUALITY, little erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Coastal plains, Beachwoods</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>- Swamp, Histosols and Gleysols</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>MEDIUM QUALITY, moderate erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Alluvial/ alluvial terraces</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>- Chronos Histosols, low talasiga</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>MEDIUM QUALITY, serious liability to erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Steep slopes, Mystic Cambisols, forested</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>- Lower slopes, Eutric Cambisols, now reed thicket</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>VERY MEDIUM QUALITY, significant erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Plateaus, Arctic Ferrosols, now talasiga</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>VERY MEDIUM QUALITY, serious liability to erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Hills and slopes, Ferralic Cambisols and Studio Ferrosols, now talasiga</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>LOW QUALITY, serious liability to erosion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Very steep slopes, Mystic Cambisols, now</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

Key to symbols: ++ highly suitable; +++ suitable; ++ low chance of success; -- land use type not suitable

This study, carried out on plantations from five to 15 years in age, yielded significant evidence of net amelioration of the soil in the planted areas; moreover, there was also an enrichment of the spontaneous ground flora. Positive consequences of pine planting on soil permeability have earlier been demonstrated by Bayliss-Smith (1977). It perhaps follows that the establishment of a continuous ground cover under Fimus caribius is beneficial both to the soil and...
to the hydrological regime. At this stage, a significant tendency toward degradation of soil under the trees could be discerned.

The effect of shifting cultivation. In view of the widespread development of permanent cultivated field plots on steep slopes, it was deemed necessary to determine the effect of forest clearing for this type of agriculture. Shifting cultivation is the result of an adaptive response of these closely related if not independent islands, but there has been considerable research devoted to these. There has been little marketing opportunities for taro and yam and a significant decrease in surveys or studies of the field. It was possible to measure the amount of soil erosion from the sediment deposited in a stream of the base of a forested hill, which has been cleared and cultivated (21st style). This was not a complete satisfactory method, but sediment traps would be preferable. Not only is it impossible to separate sediment derived from the cleared area and the uncut slope, but the amount of erosion is also under-estimated, since quantities of material contained within the sediment traps would have been preferable. Not only is it impossible to separate sediment derived from the cleared area and the uncut slope, but the amount of erosion is also under-estimated, since quantities of material contained within the sediment traps would have been preferable.

The inescapable conclusion was that an ecological balance had been achieved in a valley used for food production in Fiji. None the less, this conclusion was based on the assumption that no significant changes had taken place in the use of land between 1898 and 1961. Nevertheless, this was not the case, and the study of the soil-vegetation complex within the Fiji project was designed to explore this problem, as well as to establish the basis for an evaluation of land resources in terms of their rational use.

The study of the soil-vegetation complex within the Fiji project was designed to explore this problem, as well as to establish the basis for an evaluation of land resources in terms of their rational use. One range of field studies was therefore undertaken, calling not only on soil, but also on geomorphology, sedimentology, agronomy and botany. Limitations of competence were encountered, yet while project members were selected for their interdisciplinary interests, the primary expertise of the ecological team was in the field of geomorphology, one. The need for specialists was not made available to advise the team in the field. Existing documentation and unpublished section of material provided by the geologists of the Mineral Resources Division, the pedological studies of Twyford and Wright (1965), the botanical studies of Parham (1972) and a good aerial photography coverage from high, middle and low altitudes for Lakeba, and middle and high altitudes for other islands, had to subdivide as the base of inquiry. Further information was obtained from the local professional services — meteorology, agriculture and forestry — and also from unskilled and well-informed guides in the field. The larger part of the botanical work, in particular, was achieved by relating vernacular names obtained in the field to the data provided by Parham (1972) and specimens in the Suva herbarium.

Inevitably, more questions were posed than were answered in the course of the ecological survey demanded solution through research in geomorphology, botany and palaeontology. Often, the problems of forest clearance and the establishment of a quarternary chronology for the Fiji region, an exploration of the Box-Batman soils on Lakeba, and of the origin of the talasaga formation. Partial answers could be suggested only on the second question because a whole research project to itself alone. Even the adhocratic study of soils had to rest at a level of descriptive quality. Fossil analysis would be necessary in order to detect deficiencies. Pot trials would also have to be done. If all this the project would have required more specialists, more time and more money.

Preliminary study of the effects of increased man's impact on land is not impressive. Without it was not possible to go beyond the reconnaissance work described above in view of limitations of time and resources in this pilot project.

CONCLUSION

The study of the soil-vegetation complex within the Fiji project was designed to explore the changes that have taken place, as well as to establish the basis for an evaluation of land resources in terms of their rational use. 1

1 (Editorial footnote) The principal author of the present paper in particular was selected for this reason.

BIBLIOGRAPHY

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The land-sea interface of small tropical islands: morphodynamics and man

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INTRODUCTION

Physically and biologically islands are discrete entities in many obvious ways; there is a sharp discontinuity between land and sea not only in ambient medium but also in landform, fauna and flora. The land-sea interface clearly delineates the foreshore from the marine environment, and the organization of the Fiji project into island survey and marine survey teams illustrates this division. And yet the land-sea interface, even in tropical areas of low tidal range, is not just a single line separating the terrestrial and the oceanic domains; nor is it solely the zone between high and low water marks, though this may be its geographical focus. Rather it is a transition zone of indeterminate and variable width around the perimeter of a single island characterized by interactions between land and sea. For convenience this transition zone can be called the insular coastal zone, for it is not wholly terrestrial nor wholly marine but a combination of the two. In a static sense some coastal features of small islands owe their salient characteristics essentially to the geology and topography of the land, examples being the coastal cliffs, scarp and valleys of volcanic and limestone islands; others such as tidal flats, reefs, lagoons and sedimentary accumulations are more intimately connected with the ocean. In a dynamic sense there is a considerable number of physical and biotic interactions which closely link the insular and marine environments in exchanges of energy and materials. Salt and freshwater passing into the ocean from island slopes affect marine communities; salts from sea spray blowing inland from the coast affects terrestrial communities. Indeed some organic material on islands ultimately has a marine origin, such as phosphatic deposits from guano deposited by fish-eating sea birds.

In the coastal zone itself the linkage between sea and land is nowhere better illustrated than in the low sandy flats or berm which occur continuously or discontinuously around many volcanic and limestone islands in the tropics and provide the sites of many contemporary village settlements. The parent material of these lowlands is the whole derived from the adjacent reef and not from the land; they can logically be considered as an extension of the reef ecosystem in the same way as reef islands and atoll motu. The nature, origin and development of these features is considered in some detail below to illustrate the interactions between sea and land in a zone between external and internal environmental processes. Some more general aspects of the coastal zone will also be considered briefly, notably its diversity and resources, for close proximity to a range of terrestrial and marine environments and resources is surely one major reason for the fact that settlement on small islands is so frequently coastal. Illustrations are taken from two of the eastern islands of Fiji investigated during the Fiji project - the volcanic island of Lakeba and limestone island of Kabua - and from the atoll of Funafuti in Tuvalu to the north of Fiji. These are very contrasted islands; each can be considered as representative of the three major types of small islands in the Pacific - limestone, volcanic and sea level reef islands. Detailed descriptions of Kabua and Lakeba and their reef-lagoon systems are given in Brookfield (1978,1979), while Funafuti is described by David and Sweet (1904). The general geologic, climatic and oceanographic setting of all three islands is covered in another contribution to this Technical Note by R.F. McLean. The approach of the present contribution to the land-sea interface is that of a coastal geomorphologist and

not a social scientist; but since most is-
landers are coastal people and since much island development — past, present and
future — is closely related to the coast, the
approach is appropriate.

DIMENSIONS OF THE LAND-
SEA INTERFACE

The land-sea interface on small islands can be considered as roughly analogous with the
coastal zone. Though there is an immense
variety of tropical island types, limestone, volcanic and sedimentary, two features are
common to most: coral reefs and littoral
vegetation. Both occur in the coastal zone
which is here understood as including all
that zone from the outer reef edge extending
broadly seaward as far as marine-induced geomor-
phic and sedimentary processes are likely to
interact with subaerial ones, and as far inland
as the vegetation, soils and ground-
water are markedly affected by the marine en-
vironment. One justification for this defini-
tion is that it treats the insular coast as a
unitary physical environmental system.

Clearly the coastal physiography is the re-
sult of the interaction of a large number of
physical and biological inputs including at-
mospheric, oceanographic, tidal and
wave effects, tectonic and lithologic effects, reef productivity and sedimentation, all
mediated by the physical and biological diver-
sity of environments encompassed within
the coastal zone is the basis of its popularity
for nearly all tourist purposes, as well as the
basis for its use as a multiple resource. These
environments vary over very short distances
both across and along the shore.

Because they completely enclose the sub-
Aerial landmass, island shorelines are later-
ally continuous. This fact is important.

The coastlines of continental countries, island shorelines face in all di-
rections through 360 degrees. They therefore
have the potential to be impacted by wind,
waves, currents and storms from all points of
the compass. Recently, if ever, however, the
distribution of processes uniform around
an island. Instead there are usually strong
spatial variations in the intensity of pro-
cesses, most notably and consistently between
the rough windward and calm leeward sides of
tropical islands in the trade wind belt. This
fact alone makes for great environmental vari-
ability around an island regardless of whether
the geomorphic structure and topography of
the coast are laterally homogeneous or highly
variable.

Secondly, the planimetric geometry of shore-
line development is highly variable. Every
imaginable shape can be found; islands are
electronically circular (e.g. Lak-
eba), crescentic (e.g. Kabara, Funa-
futi), others indented (e.g. Lakeba), others
highly irregular. The greater the degree of
wiggliness of the island the less the numerable
of locally sheltered and exposed coastal en-
vironments.

Thirdly, the combination of first and second order shapes is partly reflected in the
shoreline's actual length and in the rela-
tion between shoreline length and island
size. Just as island size is an important
ecological and biogeographical variable, so too is the length of shoreline. The domin-
antly volcanic island of Lakeba has an area
of 36 km² and shoreline length of about
31 km while the dominantly limestone island
of Kabara has an area of 43 km² and shoreline
length of about 23 km. By way of contrast the
total dry land area of all the atolls on the
atolls of Funafuti is only 2.4 km² and yet
the total length of atoll shoreline is about
three basic zones; first, the island's coastline
solely a function of island size; nor is
diversity simply a function of is-
land size.

In addition to marked lateral changes in
environments resulting from variations in island size, there are also great
change across-shore variations. Sandbanks
between the marine and terrestrial is a sor-
cellular system of horizontal and vertical
xonal within the coastal zone. Seaward to
landward these may include the reef slope
and its back, the outer reef flat, the near
beach or mangrove swamp, sandy lagoon or
rocky shore, and fossil cliffs or cliffs.

Depending on local conditions, some zones
may be absent or there may be additional fea-
tures. Variations between and within islands
can be great. On Lakeba all of the above
zones are present but their extent and details
are highly variable with a particularly marked
contact between the island's eastern and
western coastlines. Kabara on the other hand
has a relatively simple and uniform reef to
lagoon to sandy beach to cliff sequence al-
t Net however many places the beach is absent.
Funafuti, being an atoll, is even simpler; it has
three basic zones - outer reef flat - lagoon -
reareal but generalizations such as
does not do justice to the great wealth and
variety of habitats that are present.

Additionally the range of zonal environments
may be concentrated into a horizontal dis-
tance off a few tens of metres or expanded
over a kilometre or more. Generally speak-
ing the broader the area the greater its
diversity though this does not always follow.

Frequently the total length of the coastal zone
is large relative to island size. In the
case of Kabara, addition of the whole coastal
zone to the island would add about half the size again to the island and in the
case of Lakeba it would double the island's total area. Generally, the popula-
tion carrying capacity' of small islands should include the whole of the coastal zone
and not just the terrestrial landmass, though
this has never been done.

CHANGING NATURE OF THE
COASTAL ZONE

The dimensions of the coastal zone, its
length and width, plan and profile proper-
ties, and lateral and zonal organisation, type and range of biophysical environments
are not, however, invariable. It depends on
many factors, and some of which are
altered by human activities on the island, e.g.
water supply, irrigation, drainage, etc.

The coastal zone of Lakeba is an example
of a zone that has undergone a significant
change. The zone, as defined by McLean,
was divided into three main sections:

- The beach area, comprising the near-
beach and reef flats.
- The lagoon, an area of shallow water
between the reef and island.
- The terrestrial area, the landmass itself.

When the first British expedition visited
Lakeba in 1808, the island was largely
covered by mangrove forest, with only small
patches of open ground visible. Over the
next century, the island underwent a
significant change in vegetation due to clima-
tic and human activities. The mangrove
forest was cleared for agricultural land,
and the open space was used for grazing.

Similarly, the length of island landmass
and the length of shoreline have varied
over time. In the past, the shoreline of Lakeba
was much longer than it is today, due to a
significant decrease in the level of the sea.
This has allowed for the emergence of new
islands and the expansion of existing ones.

Now, the shoreline of Lakeba is longer
than it was in the past, due to a rise in sea
level. This has caused a significant change
in the length and width of the coastal zone,
and the type and range of biophysical
environments within it. The current coastal
zone is characterised by a mixture of
mangrove forest, open ground, and
saltmarshes, with a significant increase in
the area of exposed landmass.

In summary, the coastal zone of Lakeba
has undergone a significant change over
the past century, with changes in vegetation,
length and width of the coastal zone, and
the type and range of biophysical en-
vironments.

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the largest of the Tuamotu Islands.

Journal of the Polynesian Society, 69(1),
37-52.

Lakeba Island, Tuamotu Archipelago,
French Polynesia.
reaches growth and the constraint of a near-stationary boundary. Only with the stabilization of sea level could aggradational features, such as the coastal sand flats around the volcanic and limestone islands and coastal mudflats, begin to develop. The end of the major transgression thus saw the land area reduced to a minimum, from which it has subsequently again become enlarged.

Sea level stability and its consequences

Between four and five thousand years ago, islands reached their minimum size and first-order shoreline their minimum length. At that time the character of the land-sea interface on the volcanic and limestone islands differed markedly from the present. The coastal zone was dominated by terrestrial features; it was much narrower and much steeper except where the sea penetrated low level valleys as on Lakeh. Furthermore, because sea growth lags behind a rising sea level there was a time immediately after it had stabilized when wave activity was not damped or excluded or so much as today by peripheral reefs. Waves beat against the terrestrial landmass along steep ephemeral cliffs and scarps. Features of this situation can be seen in the relict cliffs and truncated hillslopes which back many of the coastal plains and lowlands Lakeh and sandy flats around Karah. At that time the sea level stood at levels such as Funafuti were essentially the same, the reefs being above at low water. These conditions vary, however, quite temporary. With the stabilization of sea level (its present state), the wave growth and wave flat growth could catch up and reach the surface, bringing an apparent decrease in energy both across reef flats and onto islands protected by peripheral reefs and/or shallow lagoons. The coastal zone was now broader than before and its basic dimensions were akin to those of the present day with its seaward extent being marked by the reef's edge. Clearly this situation was reached at different times in different places depending on local conditions; indeed in some localities, such as along the clipped open northern coast between the villages of Tokolau and Nakelauyaga on Karah, it is still to be reached.

The detailed features of the near-stationary coastal zone thus required the combination of a near-stationary sea level and reefs at the surface. Preceding conditions for development. Based on evidence from Lakeh these conditions were achieved at most 4-5000 years ago. Once achieved, however, the accumulation of coastal alluvium was not ceased since there was a ready supply of reefal sediment available for deposition and quieter wave conditions on the volcanic and limestone islands and sand flats around Lakeh and Karah. As a result of normal wave and current activity, the volcanic islands started to build up the island lagoons, swamps and intertidal bars of today. These deposits represent local, pre-existing marine sediments and tidal flat development. The parent material of the limestone islands and all of the sea level reef islands and atoll is derived from the reef-lagoon system, with the surface and other reefal and lagoon organisms such as molluscs, calcareous algae and ferromanganese nodules. This is also basically true on the volcanic islands as well though mud and pebbles from hillwash and stratae are locally intertided in the deposits making their three dimensional stratigraphy rather more complex. Clearly the pre-existent coastal changes nor their recession should be underestimated. Some idea of both can be gauged from data collected over the years by the study of the coastal lowlands of Karah and Lakeh. On Lakeh, at a distance of 260 m inland from the present beach, the depth at 130 m beneath the land surface, was deposited reef sand was radiometrically dated to 275±135 years ago, while from widely separated localities were dated at 1875±125 years BP (UX-4477) and 2045±130 years BP (UX-4478). The former was a deposit of 2.2 m at a site 175 m landward of the beach, the second from 0.5 m depth, 200 m inland from the present beach. The age of the reef flat sand is not known in detail, these data indicate very substantial progradation of the reef flat. That this growth was periodically affected by catastrophic storm wave and hurricane erosion and deposition is clear from the presence of massive reef blocks on reef flats of Lakeh, Karah and Funafuti, as well as from the presence of layers of pumice and coral rubble stratified within the sandy lagoons at Lakeh and atoll motu. On the volcanic islands, not only reef-derived materials were available, land-derived sediments were swept to the coast during episodes of high rainfall. In some valley on Lakeh alluvium and colluvium completely

vemeets the coral sand foundation right to the shoreline. It is relevant to note here that these and other processes were witnessed by man himself. People have lived on Lakeh and Karah for at least three thousand years. Changes of changing shoreline geography were obviously important for prehistoric occupation. In that time people could make all sites and rock shelters at the foot of coastal lowlands and occupy the new flat land it was as being covered by waves. With the development of coastal lowlands, sandy plains and lagoons were covered with sediments and the area available for active sediment production reduced. Combined with the fact that surface reef crasts and flats are now almost barren of living coral, and that wave energy is diminished by the seaward growth of the reefs and locally the expansion of mangroves, this has resulted in an impoverished sediment supply and reduced capacity for sediment transport. On Lakeh this situation has almost certainly been reached, while on Karah sediment is still supplied to the sand flats from the adjacent lagoon, though in diminishing quantities. Such local contrasts are to be expected. They result from differential internal adjustments to the diastrophism that has brought about the present position some 4-5000 years ago. Clearly then the legacy of sea level history and its consequences still stand on the present day.

CONCLUSION

The attractiveness of the coastal lowlands for prehistoric settlement was generally poor except for certain coastal lagoons and lagoons around the villages. On Lakeh the seashore, and at about 1000 years ago, the area is occupied by the local village, Tutu. In the receding swamp, artifacts of prehistoric time are frequently exposed and swept to the shore. This apparent paradox of eroding beaches bordering richly productive areas as though there is a global phenomenon. Possible causes include an increase in storms, rearrangement around Lakeh land and interaction by man with natural shore processes. On small tropical reef-ligared islands there is the additional and potentially more important of our previous discussion that of a diminished sand supply from adjacent reefs and lagoons to the coastal lowlands. beach-graded seaside greater proportions of reef flat and lagoons were covered with sedimentary accumulations and the area available for active sediment production reduced. Combined with the fact that surface reef crasts and flats are now almost barren of living coral, and that wave energy is diminished by the seaward growth of the reefs and locally the expansion of mangroves, this has resulted in an impoverished sediment supply and reduced capacity for sediment transport. On Lakeh this situation has almost certainly been reached, while on Karah sediment is still supplied to the sand flats from the adjacent lagoon, though in diminishing quantities. Such local contrasts are to be expected. They result from differential internal adjustments to the diastrophism that has brought about the present position some 4-5000 years ago. Clearly then the legacy of sea level history and its consequences still stand on contemporary modernization.
The living marine resources of the South Pacific - past, present and future

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I. THE MEANING OF 'MARINE RESOURCES'

INTRODUCTION

The oceanic environment - huge seas, coastal zone and oceanic depths alike - cannot be studied apart from the atmosphere, the terrestrial biosphere and the geology of the ocean floors. Both the living and inert elements of the ocean and its depths comprise elements related to those of the adjacent environments. In discussion of 'resources' it is normal to draw a distinction between 'renewable' and 'non-renewable' resources. In the oceanic environment renewable resources include all forms of plant and animal life, while non-renewable resources arise either from accumulation of the products of biological cycles - petroleum, coral limestone and globigerinal ooze of the depths - or from chemical reactions within the oceans - manganese nodules - or from elements of geochemical origin.

However, the term 'resource' also implies the capacity for human use and exploitation. Elements of the oceanic environment which have never been used by man cannot be described as resources in the context of present or past technology. If confusion and misunderstanding are to be avoided, it is necessary to draw a fine line, and the criterion employed here is that 'resources' are those elements which will be used by man on a collective scale. Thus, for example, we might say that the fish caught in the lagoon of a small island are as much a resource as its production of copra and rice, while a small shell occasionally collected by children or women for domestic use does not belong in the same category. This distinction is important, and is sustained throughout the discussion of this paper.

As of now, therefore, many elements of the marine environment are not 'resources' because they have never been exploited. However, the range of exploited elements has not remained constant in the past, and is likely to enlarge in the future so that ultimately all elements of the oceanic environment may come to be thought of as potential resources. Already it is possible to foresee the exploitation of polymetallic nodules, and of pharmacodynamic substances extracted from marine organisms. It is not possible to foresee what will be regarded as resources 30, 50 or 100 years hence. One hundred and fifty years ago pearl cultivation was unknown; only 30 years ago there was no conception that polymetallic nodules on the ocean floor might come to be exploited. The concept of resources is therefore both relative and dynamic, and is particularly dynamic at the present time in the marine domain.

The extractive nature of the marine harvest

On land, a high proportion of man's total harvest is produced by cultivation and breeding, but this is not true of the oceans. Marine products collected or otherwise obtained by man can be estimated at some 60 million tonnes annually (1976), and of this total harvested biomass approximately 95 per cent is derived from fishing and collection, and only five per cent from aquaculture. It would be appropriate to add some ten million tonnes obtained from land to this total, but in this paper only the oceanic harvest is discussed.

There have been great changes in the pressure on marine resources in modern times. So long as only the harpoon and line were employed for fishing, and the canoe or small sailing vessel as vehicles, there was no threat to...
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Marine life. However, the technology of modern times has made possible the evolution of fishing systems which operate on a completely different scale from the earlier systems. The impact of these new systems on marine life is serious, for the harvest is taken from normal natural productivity, and it is easy to surpass the limits at which depletion of the cropped species becomes inevitable. On land, man has long ago moved from hunting to agriculture, but such a transition has scarcely begun at sea. The range of modern technology applied to what remains a hunting and gathering industry is alarming. It includes factory-ships to collect and preserve the harvest of the hunters; use of satellites to detect the presence of large shoals of fish; growth in the size of fleets and of ships. The effect of these developments, and of the growing food demands of a rising world population, has already included serious depletion of tuna, anchovy and whale, and threatens the extinction of some whale species in particular.

Major trends in the world fishing industry

The growth of activity

The tonnage of fish harvested has multiplied 30 times in 100 years and has doubled during the last 20 years. About 70 per cent of the present catch is composed of pelagic species and fish of the middle depths (anchovy, herring, mackerel, tuna, etc.), and most of the remaining consists of demersal species (cod, snapper, etc.). Less than eight per cent consists of invertebrates (molluscs, shellfish, etc.). Over 70 per cent of the total annual catch is made up of only seven families, all of which have been fished for more than a century. While 27 per cent of the harvest is consumed fresh by man, 18 per cent after freezing, 13 per cent canned and 11 per cent salted, it must be noted that the total nutritive value is 31 per cent of the original, and that this is a much lower figure than that of fish-flour. This latter is used only to feed animals, or as fertilizer, and the quantities are small compared to that of fish-flour. During the last decade we shall return to this question below. The fishing industry has now spread to every part of the oceans where fish are to be found, but the creation of 100-nm (370 km) 'economic zones' will reduce the area of exploitation because of the ever-increasing demand for fish. Altogether, these zones provide 88 per cent of the total catch.

World-wide fishing perceptions

Authorities place the maximum potential catch, consistent with maintenance of the total fish biomass, at 50-100 million tonnes, of which between 55 and 100 million tonnes, the present annual catch is around 60 million tonnes. Emotionalists maintain that over-exploitation is already a fact; even the optimists allow only a narrow margin. However, the concept of 'resources' again becomes important. Man does not yet exploit the full potential of the Atlantic waters, but if these and other species come to be employed, the maximum potential catch might be raised as high as 335 million tonnes.

Aquaculture

In the traditional range of energy inputs supplied by the 'cultivator', the term aquaculture covers a wide range of activities. At one end of a continuum is the breeding of oysters whose entire nutrition is derived from their natural environment; at the other is the cultivation of fish in closed ponds or tanks, where all food and fertilizer are supplied from outside. The first system rarely intercepts nutrients which might otherwise enter natural food webs, while the other is partly self-sustaining. However, measured in financial or in energy and nutrient throughput, the differences are as much as range as range of agriculture and simple statements are not possible.

Ultimate limits to the marine food resources

Discussion of the nature of aquaculture serves to underline the ultimately limited nature of marine food resources, even though the limits may lie well beyond present estimates. Unless nutrients are imported from the land, and hence subtracted from the productivity of terrestrial ecosystems, they all derive ultimately from the process of photosynthesis, requiring light, nutrient minerals and carbon dioxide. By far the major part of primary production in the marine system consists of phytoplankton, some 98 per cent of the worldwide biomass. However, benthic algae clining on the sea bed and symbiotic algae (living in symbiosis with animals) are significant out of the productive 'trophic' zone, and there are many important species in the areas available for free fishing from about 70 per cent to 50 per cent. Almost all of the

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Since they include algae in symbiosis with coastal resources, the coastal ecosystem is essentially that of the continental shelf and there are generally three trophic levels between the primary food base and the hering. In the upwelling zones only two trophic levels separate the phytoplankton, via the zooplankton, and the anchovy.

The selection nature of man's harvest

Two areas of the ocean may thus have similar primary production and similar flora and fauna, but only 'fertile', but the resource exploited by man will be far greater if it is drawn from the second trophic level than from the fifth. Given the 'law of tench', the difference will have a magnitude of 1000. Everything, therefore, depends on the nature of man's levy on the marine resources, and this depends on technology, technology and economic considerations. In the Antarctic, for example, man has exploited the whales at the third trophic level almost to extinction; technology now permits exploitation of the krill (second trophic level) on which the whales feed. In some instances, however, men has begun his exploitation at the fourth or fifth, with the first level. We shall examine this latter situation further in relation to the second and fifth, with the first level, the 'mother-of-pearl' shell and other molluscs.

It follows that there is no simple correlation between the fertility of an oceanic environment and the abundance of its natural resources. In any given area, resources will be abundant if they are exploited at a low trophic level, but this is not often the case, since primary production determines the volume of primary productivity. The volume of primary productivity is the product of the productive area available for fish food and the size of the fish population. The problem then becomes one of growth and demand, and hence the price that can economically be paid. If fish are to be caught at a price which will pay itself after then themselves be diverted from the natural food web and their ultimate productivity will remain subject to the constant value. There is no escape from this loss until unless man is himself able and willing to employ only the primary productivity of the oceans.
II. THE MAIN ELEMENTS OF ENVIRONMENT IN THE PACIFIC

THE SOUTH PACIFIC REGION

It will be convenient to define the south Pacific as that area of the region south of the area of operation of the South Pacific Commission, including the archipelago of Polynesia, Micronesia, Melanesia, the Cook Islands, American Samoa, Western Samoa, Niue, Tonga, Tokelau, the Gilbert Islands, and the Trust Territory of Micronesia. Papua New Guinea is included only as the context requires, and the areas of Hawaii, New Zealand and Australia are excluded. We are therefore dealing with the southwest and central-west regions of the Pacific, a region extending over some 100 degrees of longitude and living almost wholly within the tropics. The region comprises 9 of the 11 nations of the Pacific, and the largest number of islands, with many thousands of islands and a total human population of some two million, excluding Papua New Guinea, or 4,700,000 including the latter.

The principal physical characteristics of this region have been described many times, and need only be summarized. The distinction between the high, volcanic islands and the low, atoll islands is fundamental. Most of the former are quite small, with the exception of New Britain (37,000 km²) and New Ireland, which is the largest island in the eastern part of the region. Among atolls (300 in this south Pacific region), that of Rangiroa in the Tuamotus of French Polynesia, being 140 km in length, and most are far smaller. Lagoons generally reach a depth of 10 to 60 m, the larger number of closed atolls having much shallower lagoons. A fact of major importance throughout the whole region is the absence of any continental shelf; although the submerged slopes of the islands are important, they are small in area and isolated. The past human use of resources in this region has been confined mainly to the land, and to the immediate offshore waters. Sufficient supply of marine foods was available on the coast, in the lagoons and around the reefs, and it was only rarely that islanders ventured onto the ocean in search of tuna and bonito. Historically, therefore, there was never any need to exploit the resources of the ocean itself, or to develop technology capable of such exploitation. Even in modern times, the whole region has depended overwhelmingly on its coasts, exports, and the only major extractive resource exploited for export have been minerals - nickel and phosphates. Only in Fiji has the commercial agriculture economy become substantial, and in the Philippines, which has certain marine resources have been or become important in commerce, their exploitation has been used to replace the economy as a whole by the island economies.

Marine resources and their distribution

In the whole of this region there is no important zone of upwelling from the depths. The waters are oligotrophic systems, and there is no large input of nutrients from adjacent land masses which might favour primary productivity. Moreover, the thermocline - the level at which colder but richer waters are encountered is everywhere at fair depth. While the oceans themselves are relatively barren, however, the coastal areas have great richness in coral. The coral communities which surround these islands are among the most complete systems on earth. This extraordinary contrast demands explanation. The coral reef ecosystem is itself the most remarkable instance of symbiosis between animals (the madreporites and some other organisms) and algae, which inhabit their tissues. The whole food web of these isolated ecosystems depends on these algae trapped by animals, and analogous in other respects to the fringe algae in the tropical lagoons in the oceans. An important consequence of this symbiosis is that energy losses between trophic levels are reduced to a minimum. Moreover, the coral community has developed mechanisms with which to supply itself with indispensable nitrogen and to recycle acquired phosphorus, within a larger oceanic environment characterized by extreme poverty in these elements. In addition, the mucous and detritus created by these symbiotic algae are fundamental to all trophic interrelationships among the coral communities. The richness of this community is thus a remarkable natural adaptation to a quasi-desertic environment.

The contrast between oceanic poverty and coralline wealth prevails throughout the region and is a characteristic of the coasts of the ocean itself, or to develop technology capable of such exploitation.
while Tahiti statistics show that 50 000 tonnes have been exported since 1877, the total export was probably two or three times this figure. Many ships cleared directly from New Caledonia to Tahiti, but the heaviest pillage was already over before 1877. Production in French Polynesia has actually been limited between periods of 643 tonnes in 1833 and 1319 tonnes in 1924, and troughs of 179 tonnes in 1850 and 60 tonnes in 1931. From the outset of the business, diving for mother-of-pearl has been an important social and economic activity in eastern Polynesia. Several thousand persons, including divers, traders and their families, moved to the atolls—there were 4000 at Bikar in 1921 (Hervey 1934; Legrand 1950). Marures Sud and Takaroa were the most productive atolls (Sonneage 1966). Mention of depletion of the stocks emerges in official reports as early as 1863, and efforts began thereafter to regulate the harvest. These measures included a rotation of lagoons open for diving and their division into sectors, declaration of limited diving seasons, imposition of quotas and prohibition on taking small shells, but they had limited effect. Palliation of the supply and the use of polyvalent lagoons as substitutes led to a steep decline in production between 1969 and 1977 (183, 187 and 75 tonnes, respectively—see preceding years). In 1977 shell accounted for less than 0.4 per cent of the total exports of the Cook Islands. Some years ago a factory was established in French Polynesia, but it was designed for a maximum annual output of 25 tonnes, and quickly failed (Reed 1973).

A similar story can be recounted in the Cook Islands. Over the years, the number of divers from these islands being recruited for work in the Gambier group in 1802 (Reed 1973, p. 78). Twenty years ago, mother-of-pearl shell was still the principal export of the Cook Islands, but there has since been a rapid decline. In 1976, 94 per cent of the remaining world production came from the Philippines, and no Pacific country produced more than a few tonnes. Fiji production was 10 tonnes.

This classic case of over-exploitation has reduced a renewable natural resource to an extremely low level. However, the mother-of-pearl oyster is indispensable for the new industries of exportation described later, and there is active research on ways of re-creating the resource. A complete halt to the small residual exploitation for a long period of years is one method. Laboratory cultivation from collected oyster embryos has successfully been carried out by the Fisheries Service in French Polynesia. In Tahiti, the possibility of re-stocking the depleted lagoons. However, the exploitation of natural stocks is no longer possible, since the population is too small through population methods that the industry can be re-established.

Trocus shell

The Trocus niloticus is naturally widespread in the western Indian Ocean and Indian Ocean, and the Solomon Islands to Papua. This thick conch shell has been collected for use in the button industry since the beginning of the 20th century, and especially around New Caledonia, and the annual level of exports still holds around a 1000 tonnes; in 70 years more than 30 000 tonnes have been exported. However, there have been increasing problems due to exhaustion of stocks, leading to a shift from low-value collection to diving, and search over wider areas. Stocks already reduced before 1940 were reconstituted during World War II when there was little exploitation. The use of byproducts is still possible in French Polynesia. Regulations have been continually modified, and more recently conflict has arisen between the local divers and the Polynesian immigrants who have entered the business. Elsewhere in the region, in the Cook Islands and Fiji, trocous has been exported intermittently since World War II, but harvests have never exceeded 300 tonnes. Two factories were established in Fiji some 30 years ago, but they lasted only a short time. Though threatened, this resource is still in being, but it constitutes only a minor element in the economy and offers no secure base for higher levels of development. Some efforts have been made to transplant trocous into areas where it is not naturally present, in Micronesia and Polynesia. The Japanese succeeded at Tikou and Tepa, but failed elsewhere. Fifty specimens were brought to French Polynesia from the New Hebrides in 1957, and were successfully established at Tahiti and Moorea, but the experiment failed at other islands, including Huahine. One of the factors has been large fluctuations in price, but has totalled 578 tonnes since 1972. In addition between 150 and 200 tonnes are used locally each year for the manufacture of bracelets and curios for sale to tourists. Fishery statistics for 1975 show only Fiji and the Solomon Islands within the region (225 and 480 tonnes respectively), but 12 tonnes from French Polynesia should probably be added.

Burga

This large, globular gastropod (Turbo sarmaticus) is widely distributed in the western and central Indian Ocean, and extends as far as the New Hebrides and Papua New Guinea. However, the technology remained until after World War II and even then development elsewhere proved difficult because the necessary conditions are only just found in conjugation. In the Torres Strait area of Australia the cultivation of Plectos pectum was begun in 1936, and the number of pearl farms increased to eight in 1962 and 15 in 1965 (Masar 1969; George 1971; 1969). Plectos pectum is native to New Guinea and New Caledonia, but occurs almost abundantly in Torres Strait. Plectos pectum is therefore a Pacific species of oysters. It has also been used for pearl cultivation in this case of the black pearl produced by the pearl farm. Within the present region, this activity is confined to French Polynesia where, despite the depression discussed above, Plectos pectum remains more abundant than elsewhere. Japanese specialists, brought to French Polynesia by the Fisheries Service, have taught the delicate technique of grafting to obtain round pearls to several groups of co-operatives, especially in the Tuamotu group. Co-operatives have been formed and four private groups have opened five farms in the Tuamotu and Gambier islands. In 1976 the value of exported production approximated US $165 000, and this represented only three per cent of the Territory's exports. It ranked second after copra. The industry is now becoming an important source of income, and production fluctuates greatly by the quality of the oysters. It is the work of the experimental work discussed above is of critical importance. The feeding of the oysters from collections of the embryo or larvae takes place at a very far more rapid rebuilding of stocks than by natural means. At the beginning of 1978 the American Institute of Gemology provided official authentication of the natural un-treated status of Polynesia pearls, and it is possible that their value on the international market will rise in consequence. Pearls are a product of high value, and once the technical and marketing problems are solved, it seems likely that this industry can grow into a major and fairly export activity. This noteworthy development is of double interest from the present point of view. First, it relies on a natural, renewable resource successfully managed; second, it is an activity of the outer atolls, environments which elsewhere in the region offer extremely limited cash-earning possibilities to their inhabitants.

Collectors' shells

Throughout the South Pacific a small, though far from negligible trade in decorative shells has been going on for many years, and this amplifies the spread of tourism through the region. A distinction needs to be drawn between the simple collection of typical shells and the collection of selected species into necklaces and curios. Shell necklaces are made everywhere in the region, especially in French Polynesia where they constitute customary parting gifts, complementing the floral leis given to visitors on arrival. Several types of casual Fig préparé and Opae are used for this purpose each year, without seeming to pose any risk of over-collection. The sale of shells, both to indiscriminate tourists and to more knowledgeable buyers, is an important element in petty commerce in all Pacific countries, both in the rural areas and more particularly in the towns, where market stallholders and street vendors engage in this trade in some numbers. In cases where valuable shells are endemic to particular areas as in Tahiti and Society Islands, or to the Tuamotus and Gambiers and some others, very high prices can be obtained, especially by middlemen and professional collectors. Some
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Oyster farming has become established in the group, even though its present output is far less than the c. 100 tonnes collected, each year in New Caladonia (Pelerin 1962).

Cultivation of oysters

Although the cultivation of oysters has been discussed in the past, in the present context of a high-value industry producing pearls and mother-of-pearl shell, there is also a wider aspect that should not be overlooked. The cultivation of edible molluscs is quite highly developed and widely practised in temperate lands of both hemispheres, but is still almost unknown in the tropical Pacific. The edible oysters, of the genera Ostrea and Crassostrea require a moderately saline environment for best development, conditions such as are found in estuaries and some lagoons.

While there is no cultivation, however, there is a large natural resource, and oysters have been collected for food throughout the south Pacific since time immemorial. Two main situations are encountered: natural banks of rock oysters, as for example in the Baie de Papesi at Taiti; mangrove oysters which live on the roots of Rhizophora in habitats such as the Faarumai islands, the Solomon Islands and New Caladonia. The lagoon is in the more eastern limit of mangroves in Melanesia, and although there are no mangrove oysters, they do occur in Polynesia. Collection is in a family level, though there is a small trade in young oysters. The harvesting is not on a scale to create any danger of over-exploitation.

1966 the Fisheries Service of French Polynesia commenced work on the breeding of Crassostrea cumingii, collecting the oysters on the littoral shells close to a natural bank. This work was successful in producing commercially viable oysters (Millau 1971) and it has since been possible to establish colonies in several of the Leeward islands, where conditions are favourable. In 1974 there were a hundred oyster farmers at Fatu Hiva and Huahine, though most of them also had other activities (Drollet et al. 1973). A production of three tonnes in 1971 increased to 15 tonnes by 1974; meanwhile imports also increased, so there was no danger of market saturation. It is probable that the stocks available in the coral environment, and the slow growth of oysters, would rule out any significant expansion. Nor is there any immediate likelihood of oyster cultivation; the Japanese have not yet mastered the problems of breeding and raising this slow-growing animal in more than 20 years of research.

Molluscs as food

Molluscs are collected for food throughout the Pacific. Generally they are consumed by the collector and his family, but they are sometimes traded or bartered at the village or island level, and more rarely between islands; there is, however, almost no commercial exploitation. The oysters are everywhere important, but are selective of different species between archipelagoes and regions. Within the South Pacific archipelago, the range of species consumed is very large (Bannar 1952; Salvet 1967), but there are certain species in French Polynesia and eastern Fiji, for example, that are less numerous and belong to the following families (Salvet 1967; Salvet et al. 1977):

- Bivalves: clams (Tritonidae);
- Bivalves: clams (Tridacnidae);
- Bivalves: clams (Veneridae);
- Bivalves: clams (Pinnidae);
- Cephalopods: small octopuses;
- Gastropods: trochus (Turboidea);
- Gastropods: Strombdas; venus clams (Veneridae);
- Gastropods: small octopuses; venus clams (Veneridae);

In the Tuamotu archipelago the consumption of molluscs has been estimated at 40 g/day for each inhabitant, but at certain seasons it may rise as high as 400 g/day; at these times the intake is composed entirely of giant clams (Tridacna maxima) which are very abundant in the lagoons (de Carfort 1966). In several islands such preference for certain species has caused them to become rare, especially when the preferred species are of large size and grow only slowly; this is the case with the giant clam at Lakea, the Lau islands of Fiji (Salvet et al. 1976).

It is safe to conclude that the population of edible molluscs could not support commercial exploitation of any scale; all evidence suggests that it is already heavily taxed on the present subsistence basis. However, this situation might change were molluscs to be incorporated at some future date into a system of aquaculture.

Crustaceans and echinoderms

On a world scale, the annual catch of crustaceans totals some 2 million tonnes, more than half of it consisting of prawns. Very little of this comes from the south Pacific, where the only major enterprise is a prawn fishery in Papua New Guinea, producing 872 tonnes in 1976, almost half of the whole regional production in this group. Mangrove crabs (Scylla serrata) are also of some importance in Papua New Guinea (450 tonnes) and in Fiji (170 tonnes), and the only other harvest of significance is lobsters, of which a few thousand are caught each year in Samoa and French Polynesia. These figures, based on FAO (1976), exclude the subsistence which is substantial in certain territories, but even so it seems clear exploitation of these resources is currently at a low level in this region.

Lobsters

Lobsters, in particular, are found throughout the region, the species most common being the Portunus of the Pacific region, and one or two other species in some 30 or 40 locations in the whole region. Four to five species of the genus Panulirus are encountered in each of the archipelagoes of Melanesia, one to two in each Polynesian archipelago, but exploitation has remained at a small scale, and attempts to market have had little success. More seriously, evidence appeared - in Tonga, for example - that heavier exploitation was allowing for reduced catches and diminished size of the lobsters caught (Clutter 1972). Although small-scale commercialisation seems possible, it is probable that the stocks available in the coral environment, and the slow growth of lobsters, would rule out any significant expansion. Nor is there any immediate likelihood of lobster cultivation; the Japanese have not yet mastered the problems of breeding and raising this slow-growing animal in more than 20 years of research.

1 A complete inventory of the molluscs would also include the cephalopods of deep water, sometimes caught by the Japanese in the Coral and Tsamian Sea, although the total annual contribution of deep-water species might be quite significant. This list, however, is not at present exploitable.

The principal market for trepang has always been in China and among Chinese overseas, and has been exploited in both Indian and Pacific Oceans ever since Chinese traders and emigrants first entered these regions (Hornell 1918). Trepang is rich in protein (43 per cent) and is said to have aphrodisiac properties. Several species of holothurians of the genera Stichopus, Thelenota and Holothuria are collected and sold dried after preparation which includes emptying of fluid, cleaning and cooking (Penning 1944; Anon. 1975). The trade in trepang flourished greatly during the late 19th century and in the early 20th century; around 1900 the annual export from Truk in the Carolines was of the order of 300 000 tonnes. The main centres of commerce were in Penang, Singapore and Hong Kong, and today almost all the traffic between the countries of the west Pacific consuming countries is still channelled through the latter two ports (Sachinathan 1972). Since World War II, however, there has been a very marked reduction. The present annual trade in trepang is of the order of only 500 tonnes, not including about 13 000 tonnes produced in Japan from Stichopus japonicus. Papua New Guinea, the American Trust Territory, the Solomon Islands and Fiji are now the only exporters within the region. Present exports from Fiji amount...
to only two tonnes per year, half the level of a decade ago, but efforts are currently being made to expand production (Vatogo 1977); these efforts are part of a new drive for decentralized fish curing and drying, using simple and locally-available technology. The only factory for preparation of trepang for export is in Melbourne, but this enterprise has problems due to the need for rapid and continual supply which is difficult to ensure given the biology of the species, the problems of collection and storage. Some Pacific archipelago such as the Tuamotu group, have very large populations, such as Polynesian (Salvat 1971; 1975), but no steps have yet been taken to exploit these resources commercially. The production of trepang is capable of considerable expansion, given a more effective system of production and marketing than prevails today (Sachithananthan 1972).

IV. VERTEBRATES RESOURCES OF THE REEFS AND LAGOONS

FISH OF THE REEF-LAGOON COMPLEX

Productivity and biomass

The coral reef ecosystem is among the most important on the surface of the planet in terms of its productivity. The ecosystem occupies approximately 0.12 per cent of the earth’s surface and 0.17 per cent of the oceans. Within this total, the area with depths between 0 and 30 m represents some 15 per cent. The fish populations of these systems rest on a very rich base in primary productivity, much of which is concentrated in four to ten grammes of carbon per m²/day, while the marine plants have a production as high as 12 g C/m²/day. These levels of productivity may be compared with cultivated fields on dry land, which produce on average 4 g C m²/day. The biomass of fish living in the reef environment is of the order of 40 to 200 g/m² or tonnes/hm² (Galzin 1978), and values as high as 390 g/m² have been measured on the outer reefs of the Australian Great Barrier Reef (Salvetal and Goldman 1977). These biomass values are far higher than those reported from large lakes and coastal zones in the temperate zone (Stevenson and Hendry 1976). It should also be noted that artificial reef environments the concentration of fish population supported can rise as high as 1,700 g/m² (Randall 1963). However, these very favourable indicators for exploitation are offset by a number of constraints.

Pastors limiting the possibilities for large-scale exploitation

Great species diversity is a major characteristic of the reef-lagoon complex, and the number of species encountered is very large. A high proportion of these species is edible, in contrast to the situation in temperate zones, but in consequence the numbers of each individual edible species are far smaller than in the temperate seas. Moreover, many of the edible fishes are of small size, a fact which does not favour their commercial exploitation.

Many of the exploited species are highly territorial even within the reef-lagoon ecosystems, so that it is only in the largest such systems that major exploitation is possible without risk of rapid reduction of stocks. This is the outstanding risk in small and medium-sized systems, in which the majority of the fish are those that populate urban populations. It is also necessary to note that fish toxicity is a serious con- straint to commercial exploitation, especially as the problem of toxicity is more common and more serious among carnivorous fish that are usually readily exploited. Finally, it must also be remarked that, quite apart from the dangers of over-exploitation, the fish that are the basis of the reef-lagoon ecosystem to feel the effects of pollution and other consequences of man’s activity (Galzin 1978), is a factor that may affect the health of the fish and reduce their numbers.

Methods and technology of fishing in the reef-lagoon system

The presence of numerous coral heads in the lagoon militates against the use of modern industrial methods of fishing. Given these constraints ancient and/or individual methods have to remain the most appropriate. The former include the lance and harpoon, spear, net, and the use of Euphyra radida as poison, together with the ‘fish drive’ of Polynesia and parts of Melanesia. Among the latter the harpoon-gun is certainly modern, but requires individual operation. The use of some ‘modern’ methods such as the killing or stunning of fish with explosives can be extremely costly and has already at least partly destroyed the fish food in the lagoon at Truk (Powell 1970). Use of the trawl is feasible but other devices is possible only in those large and deep lagoons where coral heads are few and far between.

A major potential resource

These constraints explain why the fish of the reef-lagoon ecosystems have continued to be exploited on a small scale by manual methods and mainly for subsistence purposes. However, some specialists (e.g. Smith 1978) have estimated that the total fishery potential of these ecosystems may be as great as six million tonnes, about one per cent of the total harvested from the world’s seas. Present exploitation is probably less than five per cent of this potential, even if all subsistence production is included together with commercial production.

The number of species caught and consumed is very high, various to the following:

- Carrie (Scleropenis)
- Jackfish (Carapidae
- Rabbit-fish (Chlorophthalmus)
- Squirrelfish (Sargocentron)
- Goatfish (Parupeneus)
- Mullet (Mugilidae)

In addition to this, new species are being harvested as they are discovered in the surrounding oceans. This is the collection of fish for fishery into the seas closer to the land. Fish is harvested in such areas, the fish and skipjack are thus driven into the vicinity of the fishing lines. This live bait may be fished for the first resources, but is more and more derived from aquaculture. Anchovies, sardines, immature mullet, salmon, and other fish are among the fish used in this way (Ward 1977).

Present exploitation of reef and lagoon fish

Fishing in the lagoons and on the reefs has always been the main source of animal protein for the island populations of the south Pacific. It is not possible even to estimate the quantity harvested for subsistence purposes, and it is only since World War II that the growth of tourism in the islands has led to the development of formal and informal marketing channels. In the same period, Fisheries Services have been created in several Pacific countries and territories, charged with the development of commercial fishing. The task faced by these services is not easy. They have to deal with labour-intensive methods of fishing, the problem of planning and preserving the catch until it can be collected, the problems of inter-island shipping and the need to organize an appropriate marketing system. All this costly work has to be undertaken in the face of competition from imported frozen and canned fish drawn from foreign sources enjoying all the economies of scale.

The FAO statistics for 1976 show a total product of the reef-lagoon fisheries of the south Pacific countries (including Papua New Guinea) amounting to 26 300 tonnes. For the same territories, the recorded catch of tuna and skipjack totalled 66 400 tonnes (73 per cent skipjack), without taking account of the larger quantity caught by foreign companies operating in the region. The grand total of 90 000 tonnes therefore represents the FAO estimate of the commercialized local fisheries, and only 29 per cent of this is drawn from the reefs and lagoons. It is of some interest that the latter correspond to the following:

- Papua New Guinea: 15 000 tonnes
- Fiji: 3 192 tonnes
- French Polynesia: 2 075 tonnes
- Solomon Islands: 2 000 tonnes
- Western Samoa: 1 110 tonnes
- Tonga: 1 019 tonnes
- Niue: 700 tonnes
- Cook Islands: 460 tonnes
- U.S. Trust Territories: 215 tonnes
- New Hebrides: 200 tonnes
- Guam: 122 tonnes
- Solomon Islands: 70 tonnes

Excluding Papua New Guinea, the total is only 11 300 tonnes. However, this is only a part of the total, since the subsistence production has to be added. In French Polynesia, total production is estimated to be at least 4 000 tonnes, and some would regard this estimate as much too low. In French Polynesia, the writer would place the total around 6 000 tonnes, and estimates as high as 8 500 to 9 000 tonnes have been published. However, the writer would estimate that the total fish catch in the south Pacific lagoons and reefs is around 10 000 tonnes per year.

In a very interesting report, Clutter (1973) gives a soundly based development of the marine resources of the south Pacific countries.
There is a long record of failures extending over a thirty year period, and affecting almost all territories. The two principal stabling blocks have lain in the areas of planning, development, and transport, and transport to the market itself. Fiji has had such an experience with its costly Maunaloa project, (1967-70) and it would be helpful to review a more successful scheme, in which Inshore and oceanic fisheries were combined with one enterprise. In Tahiti, the Societe de Commercialisation et d'Exploitation du Poisson (SCP) was founded in 1973 with the object of developing a fishing industry mainly in the Tuamotu group, from which more than half its throughput is derived. Freezing units were installed at Fatates and at Atapaki in the Tuamotus, and a central freezing plant at Papeete (Tahiti) permitted fish to be sold, so that it could be supplied to the urban market, or exported, in accordance with demand. A sufficient supply has been established to serve the Papeete market, and it is now undergoing a small installation in the market. Some of the installations have been used successfully in the world in the past, but they are not yet published; however, they appear to stock sufficient for exploitation without large capital investment has been established. In the Negebides the French Reclit established a school of fishery in Malekula in 1921. With a catch of 15,000 tons was obtained, mostly between 100 and 200 m (Hallier 1977). The Japanese have also investigated the possibilities of rearing fish in the inshore waters on Tonga (Wilkinson 1973). Technology seems to be the principal limitation to the expansion of exploitation of these resources. However, more knowledge is also necessary, as Marshall (1977) has recently emphasized.

The Living Marine Resources of the South Pacific - Past, Present and Future

In December 1971 the catch and sale of turtles were regulated by decree. A minimum size limit was published, a limited season declared, and quotas set. Sale, and the collection of eggs were prohibited. Since then, catches of 1000 turtles a year have been raised, and released into the sea after marking. Many other turtles were also marked, and this work has led to accumulation of knowledge concerning the migration of turtles throughout the south Pacific. It is apparent that these migrations are very extensive, leading Douvering (1973) to remark that protection in one country is of little value if uncontrolled massacre of turtles continues elsewhere.

Western Samoa: establishment of hatcheries

The creation of hatcheries is strongly to be recommended. The mortality of young turtles which hatch on the sand is very high in the first hours and during the first days when they leave the beach, and cross the lagoon and reef to open sea. A hatchery has been established in Western Samoa. Eggs gathered after laying are put to hatch - a two month period - and the young turtles are then nurtured for a few weeks before being released to small groups in the open sea (Witts 1974).

Some recommendations
At present, the International Convention on trade in endangered species, which prohibits the export of turtles and their eggs, specifically excludes the green turtle (Ann. 1976a). It is questionable whether this exclusion can long continue without either disastrous diminution of the species, or alternatively new methods for their protection and rearing. Stocks of all turtles in the South Pacific are seriously reduced. Not enough is known about them scientifically, and while full turtle farming is not yet feasible it would be as well for the Pacific countries to:

- limit the development of private enterprises in turtle rearing;
- undertake intensive study of stocks, and establish statistical data;
- protect certain of the egg-laying sites from depredation;
- regulate collection (as done in some areas) and fish trade in turtles;

B. Saltant

Marine life. Geminal, snappers and emperors (Lutjanus, Priacanthidae, Auxon, Epinephelus, Lutjanus), have long been caught by individual fishermen in canoes and small boats. The fish are strong and of good size. Some Geminal are also found, including groupers and bass (Ephippidae). These fish live at all depths and have been caught at 500 m in the Cook Islands. Fishermen using traditional methods cannot tap this resource, and strong lines with manual or electric reminders are necessary to bring the catch rapidly to the surface. Fishing of this type is now practised off New Caledonia and the New Hebrides (Fournaron and Labute 1976).

Exploitation of resources

The fish stocks of this sub-system are very under-exploited, since few islanders possess the means with which to work at these depths. Even though thought there is insufficient knowledge of the constitution, abundance and distribution of species, it seems the less serious that a much heavier exploitation is possible. It is for this reason that the South Pacific Commission has undertaken a small experimental research project in the waters of the Gulf of Papua (Braithwaite 1976). This project, which was also concerned with trawl and tuna fishing, employed three vessels in the area. The results of the first year of the experiment, in the New Hebrides, Western Samoa, the Cook Islands and the Solomon Islands, the project completed its work at the end of 1977 and results have not yet been published; however, it appears that stocks sufficient for exploitation without large capital investment have been established. In the New Hebrides the French Reclit established a school of fishery on Malekula in 1921. With a catch of 15,000 tons was obtained, mostly between 120 and 180 m (Hallier 1977). The Japanese have also investigated the possibilities of rearing fish in the inshore waters on Tonga (Wilkinson 1973). Technology seems to be the principal limitation to the expansion of exploitation of these resources. However, more knowledge is also necessary, as Marshall (1977) has recently emphasized.

Turtles and Mammals

Turtles

In a region almost without terrestrial mammals, turtles have always been important as a source of animal protein other than fish. Turtles were also eaten on the sea and lay their eggs at the top of beaches in sites used for generations; there is heavy infant mortality. The sea turtle is sought after, not only for its flesh, but also for part of its stomach which is used to make soup, and for its light grey skin and shell. In addition the fat is used as a base, the eggs are gathered, and infant turtles are raised in captivity to be sold as souvenirs.

Before destroying the turtles as a resource in this region, however, it is necessary first to examine the world wide position of the sea turtle. All seven species are in danger, and are included in the Red Data Book of the International Union for the Conservation of Nature (IUCN). There is widespread discussion of turtle breeding, but too little information about what this in fact means. It is important to distinguish between the protected breeding of youngsters which are collected wild (turtle ranching), and the controlled management of the whole life cycle (turtle farming). The turtle colonies maintained in some brackish lakes in eastern Fiji, for example, fall into the former category, and there is, in fact, only one example in the world of true turtle farming. This work, on the island of Grand Casse in the Caribbean, has recently been completed with the present knowledge, turtle raising can only begin with captured young specimens, or with eggs gathered from the natural cycle of turtle farming. There is little scientific information on turtles in the south Pacific (Minter 1971: Hendrickson 1971). Statistical data are available on the turtle catch, or about the size of island resources. Among five known species in the region, only two are relatively abundant. These are the green turtle (Chelonia mydas) and the hawksbill (Eretmochelys imbricata). The world catch is listed by FAO as 7777 tons in 1976, and half of this is drawn from the Pacific. In the last year of its work the South Pacific Commission initiated a project on the sea turtle, with work in Fiji and Barotonga (Ra) and Brendan 1975, (1977). The purpose was to establish turtle ranching as an income source, but the projects did not prove viable, and were abandoned in 1976.
The living marine resources of the south Pacific - past, present and future.

The whales of the world's oceans offer a striking example of the marine resource that has been so heavily exploited that the point of complete extinction has been reached for certain species. The main whaling areas of the world have been displaced successively; whaling on the coasts of Europe ceased in the 17th century, and about the same time in the waters around Spitzbergen; the Greenland waters continued to be worked until the 19th century, and since the beginning of the 19th century, the waters between New Zealand and the Antarctic. From 1840 to 1860, but activity declined as the stock was reduced. Already in 1859 it was observed that throughout the southern hemisphere there were no whales left in the Antarctic, and all activity ceased before the end of the 19th century.

Thus it was that all commercial whaling became concentrated in Antarctic waters, but this too came to an end. The humpback whale (Megaptera novaeangliae) has a range that overlaps the Antarctic, and is an important source of whale meat. Two species were important (Lever 1964). The humpback whale has been hunted for over 200 years, and its population has declined significantly since. In 1970 and 1976 the annual tonnage of tuna, bonito and skipjack fishing by the world's fishing fleets has been between 1.6 and 2.2 million tonnes. In 1950, production of all species taken in all areas of the world was 1.6 million tonnes. By 1976, this had increased to 5.2 million tonnes. The decrease in the catch of tuna and related species has been due to overfishing and the decline in the availability of these resources.

The demand for tuna and related species has increased greatly since World War II, especially in the United States and Europe. Expansion of fishing fleets, modernization of technology, and expansion into new fishing grounds have been the response. Between 1970 and 1976 the annual tonnage of tuna, bonito and skipjack fishing by the world's fishing fleets has been between 1.6 and 2.2 million tonnes. In 1950, production of all species taken in all areas of the world was 1.6 million tonnes. By 1976, this had increased to 5.2 million tonnes. The decrease in the catch of tuna and related species has been due to overfishing and the decline in the availability of these resources.

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large joint Fijian-Japanese venture in 1976. Negotiations were also in hand in 1977 for a further shore base in the Gilber Islands. Although local capital participation was initially only small, and the benefit to the islands consisted mainly of taxes and a small amount of employment, the local share in the new ventures is larger, and includes local participation at all stages. This is particularly the case in Fiji, where it is hoped to supply the major part of the home market in canned fish, as well as export.

Meanwhile, however, purely local ventures without Japanese participation have not been successful in any Pacific country (Cupper 1973), though new attempts are being made in French Polynesia and New Caladonia.

There were some states of tuna and skippjack fishing in the region.

By 1975 the total catch of the long-line boats had risen to 80,000 tonnes, of which 50,000 tonnes was handled at Pago Pago and 13,000 tonnes at Lavuka. However, it is clear that the tuna themselves are suffering from over-exploitation, so much greater interest is now being taken in the smaller species, such as yellowtail and dogtooth skipjack. In the six south Pacific fishing zones as defined in the FAO statistics, the catch of such species rose from 8,000 tonnes in 1973 to 540,000 tonnes in 1976. Combining the FAO data with the information provided by Baird (1975) and by Lautia and Smith (1977), it is possible to estimate the production of skippack fishing in the region in 1976 as follows: Papua New Guinea 240,000 tonnes; Solomon Islands 156,000 tonnes; U.S. Trust Territory 50,000 tonnes; French Polynesia 30,000 tonnes; Fiji 70,000 tonnes; and Gilbert Islands 200 tonnes.

An under-exploited resource

There is no doubt that the skippack is a minor resource, and perhaps the major unexploited marine resource of the south Pacific. There are almost no present or no threat to the natural stock. For this reason a conference on fisheries sponsored by the South Pacific Commission in 1975 set up an expert committee on skippack fishing which, at its first meeting, established a program of statistical collection and, more importantly, initiated an extensive trawl survey to determine the numbers of fish in order to establish migratory patterns. In the first year, the skippack is migratory and it is possible to establish information only on a regional scale.

There remain serious technical problems to be overcome before skippack fishing can become a major industry. The most appropriate method is relatively labour-intensive; the catch being taken in netting with rod and line along which schools are attracted by living bait. Moreover, the provision of the bait itself calls either for commercialization of the reef and jagam fishery, with all the attendant difficulties discussed above, or else for aquaculture. The economics and strategies of such an industry are likely to impose serious problems.

Other species:

skippack fishing

Interest is also being taken in other species, in particular the skippack, which is the main domain of 'game fishing' for sport. The commercial vessels quite frequently catch skippack, but the catch goes unrecorded unless the proportion exceeds 20 per cent. Lack of data makes it difficult to express total catches either to propose any program for this species, or to undertake any measure of regulation which would be likely to prevent the species from disappearing.

Footnote by Dennis: Dr. Bernard Salt has noted that the second largest of French research workers who worked in the Fiji project on the complex of reef-lagoon resources in the eastern islands of Fiji. The results of this marine survey carried out on behalf of the project are presently in the Island Reports 4 and 5, as well as in the Project Working Paper on the conclusions of project work on the role of marine resources in eastern Fiji, as given in the first General Report. A mimeographed comprehensive report written immediately after finishing field work is available only in French.
Spatial and temporal variability of external physical controls on small island ecosystems

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INTRODUCTION

The boundary conditions for the life layer that makes up small island ecosystems are given by the land beneath, the air above and the surrounding sea. These three physical environments, one solid, one gaseous and one liquid, impinge to a lesser or greater degree on each and every island ecosystem. The meso-scale physical processes in the atmosphere, hydrosphere and lithosphere and their interactions work independently of men and at a large extent independently of the biosphere. In this sense island ecosystems, while having some degree of internal regulation, are very much dependent on a suite of large scale external factors. It is with some of these external factors and particularly their spatio-temporal variability that this section is concerned. Thus, just as the economies of most small islands are dependent to a large extent on external economic and political forces, so too it can be argued that island ecosystems are dependent on external physical forces. Both these forces are characterized by fluctuations and change, in short by variability.

Some aspects of the role of environmental variability as factors in the island ecosystem have been discussed by Stoddart and Walsh (1979), with reference to tropical islands in the Caribbean, Indian and Pacific oceans. They clearly demonstrate how, for example, merely static backdrops for human activities, island environments are themselves continuously changing, not only on the scale of recent geological time but also on scales measured in years and decades. Their conclusion, that analyses of human adaptability on islands should begin with a presumption of temporal variability in critical environmental inputs rather than with a reliance on long-term mean conditions, is an

Figure 1: Location of islands in reference area.

important one, and the present section has a similar theme. It differs in that here we consider temporal variability in one specific area in the Pacific - that extending from the equator to the Tropic of Capricorn (23°S) on the one hand and from 175°W to 175°N on the other and also covers a wider array of physical inputs than are discussed by Stoddart and Walsh. By concentrating on a specific area we seek to demonstrate not only how some physical inputs vary through time, but also how they vary over space, particularly through latitude zones. The area of reference is a large one and includes not only the eastern islands of Fiji on which the detailed work of the UNESCO/UNDP (1977) project was carried out, but also other islands of the Fiji group, western Tonga, Tuvalu, the southern Gilberts and the French island groups of Wallis and Futuna (Fig. 1). This area has been chosen because it includes a range of island types and climatic conditions.

I. PHYSICAL FACTORS OF THE LAND

ISLAND TYPES AND THEIR PLATE TECTONIC SETTING

The range of island types in this region of some 2.5 million square kilometres encompasses those found throughout much of the Pacific and includes the so-called 'low' and 'high' islands and 'oceanic' and 'continental' types. Excluding the larger Fijian islands with their complex suite of volcanic, plutonic and sedimentary rocks, the small islands can be grouped in terms of their dominant terrigenous lithological types into:

- sea level coral islands composed entirely of modern skeletal reef detritus accumulated on atoll and platform reefs;
- elevated limestone islands composed mainly or entirely of hard durable non-recent limestones;
- volcanic islands composed mainly or entirely of volcanic rocks.

Two further types can be distinguished as some of the limestone islands may have significant volcanic areas and some of the volcanic islands may have significant areas of limestone.

This classification reflects only broad categories and masks the immense variety of island forms both within and between classes. Nevertheless, the pattern shown in Figure 1 is clear; the coral islands are the only island type in the north while the volcanic and limestone islands occur in the south.

The division between these two regions is a clear one and reflects the 'plate boundary' setting of the area.

According to Coleman and Pachham (1976) the contemporary boundary between the Indian and Pacific Plates, running from New Zealand and New Guinea, strikes northward along the edge of the Tonga Trench then recurves sharply westward just south of Samoa. This recurve passes WSW through the reference area to skirt the Fijian islands, and then in a westerly direction to the New Hebrides Trench. The Vitiyo Trench to the west of Rotuma can be extrapolated eastward to link with the NW termination of the Tonga Trench and is assumed by Crook and Belbin (1978) to be a relic subduction at the edge of the Pacific Plate prior to 10 million years ago. The whole of this area forms the eastern portion of the Melanesian Borderlands, which extend from New Guinea to Tonga, and constitutes, as the name implies, a border position and broad zone of interaction between the Indian and Pacific Plates. As shown on Figure 3, the eastern Borderlands comprise a complex assemblage of norphotectonic elements consisting of island chains with small land surface, deep trenches, submarine troughs and ridges, and essentially island-arc basement area. North of the Borderlands on the Pacific Plate the sea floor is deeper, with depths of 5-6 km over large areas, and less complex, except for the atoll-like oceanic ridges and isolated highs which near 180° longitude run roughly N-S and carry the Gil-
Long-term instability: vertical and horizontal movement

While volcanic rocks form the basement of all the small islands in the region, they occur at various depths in the oceanic crust. In the southern Gilberts and Tuvalu, the basement is at great depths, at least 600 m at Funafuti and 800 m at Nukufetau Atoll (Cookell and Swallow 1953). It is overlain by a thick cap of reefal limestone accumulated on the subjacent volcanic platform, which, if the rate of subsidence is similar to that at Midway, Atwell and Bikini atolls, averaged about 20 m per one million years for the last 60 million years (Detrick and Crough 1978). By way of contrast, on the border zone and south of the Pacific Plate's present boundary, volcanic rocks and/or elevated limestone are exposed at the surface on Rotuma, Wallis and Futuna, in Tonga and throughout the Fiji group.

The geological history of this area is complex and continues to be the subject of considerable debate (see Coleman and Padgham 1976). For our purposes it is relevant mainly to note, following Gill (1976), that the basement rocks exposed in the Lau group (Lau Volcanics) are nine to six million years old and that volcaniclastic turbidites of the same age and derived from western sources are found in Tonga. These andesitic volcanic rocks are overlain on both the Lau and Tonga ridges by Pleistocene limestone which is capped in Lau by another suite of volcanic rocks (Koro-basanga Volcanics) four to three million years old. Gill (1976) uses these data to suggest that the Lau and Tonga ridges represent a once-united island arc now disrupted by rifting, which has formed the intervening Lau Basin: the rifting began about five million years ago. At least in this area, the location of islands has not been static in relatively recent geological time. Instead they have shifted horizontally over tens of kilometres, with the Lau Basin spreading at a rate of 2-4 cm per year (Scater et al. 1972). In addition to such horizontal shifts, vertical movements have also taken place. Katz (1977) believes that during the last two million years widespread deformation has occurred in the Lau Basin with faulting of considerable vertical displacement and tilting of fault blocks. It is not surprising that islands on the margins of this area display a great variety of elevations, ages and composition of both volcanic and limestone rocks. There is an obvious contrast between simple overall gradual subsidence of the volcanic basement and limestone plateau and the north of the Melanesian borderland and the complex horizontal and vertical movements of islands on the boundary zone, where the two types of rocks of equivalent age are exposed at the surface.

Contemporary instability: earthquake and volcanic activity

Contemporary instability of the Pacific Plate's boundary is indicated by earthquakes and volcanic activity, which is restricted to the southern part of the reference area and occurs there in remarkably narrow linear belts. The northern areas is seismic. Richmond (1977) points out that although about 70 per cent of the world's deep focus earthquakes are recorded from the Fiji-Tonga area, they are so deep as to not cause damage on the land surface. However, shallow earthquakes and the plate boundary areas and fracture zones can be quite damaging. In Fiji, strong earthquakes were felt in the Suva-Kadavu area in 1857, 1886, 1909, 1911, 1971, 1974, 1979, 1984, 1986, and 1987, all associated with the Suva Seismic Zone. Larger earthquakes have been confined in the Tonga Trench. In 1934 an earthquake of magnitude 8.4 was felt on Tongatapu, the island of Ha'apai causing filled ground to settle and triggering a landslide as far away as Samoa. Another magnitude 8.7 earthquake in 1934 in the same area, caused a lagoon to be uplifted and dried (Richmond 1977). The extent of the earthquake banks can also be created, and old islands added to or destroyed by volcanic activity. The main zone of contemporary activity runs NW-SE from the southwestern part of the reference region from Tonga to Niuafo'ou (Fig. 1). Funafuti-o or Falcon Island and Niuafo'ou on Tanu Island are perhaps the best known centres in this zone. Funafuti-o, an ephemeral island, has episodically emerged from the sea and disappeared during the last 100 years. In 1894 the island was 15 m high, but by 1913 it had disappeared. In 1921 it reappeared and by 1930 had grown to 147 m high, but by 1949 the island had disappeared again (Richard 1962). Larger Niuafo'ou, a permanent island, also experiences episodic activity, the 1968 eruption causing temporary abandonment by most of the island's 1200 inhabitants (Richard 1962). While terrestrial volcanic activity has not been reported outside this zone in historic time, there is evidence that at least in the eastern islands of Fiji, eruptions occurred in historic times, most recently in southern Tonga between 2000 and 1000 years ago (Brookfield 1978). In land, the very basic in island ecosystems, has thus been actively created and/or destroyed in recent times. It should also be noted that the effects of volcanic activity, both terrestrial and submarine, do not affect just a small local area. Pulses discharged into the ocean frequently drifts into the ocean in massive rafts, to be washed up on island shores or distant places. A number of volcanic eruptions have occurred on all islands throughout the whole region. This eruption derives not only from local eruptions within the region such as the submarine eruptions at Curacao Reef in Tonga in July 1973, but also from the whole of the circum-Pacific volcanic belt, which contains 88 per cent of the world's volcanoes, as well as from the South Atlantic. Thus, the islands in the region where volcanic activity is also apparent. We have already noted, on a geological time scale, how in Lau for instance the Lau volcanics were discharged 6-7 million years ago, and the Korobasanga volcanics 4-3 million years ago. On the human time scale, during the last 200 years, there have been volcanic eruptions. Figure 4 gives the numbers of volcanoes in eruption in the circum-Pacific volcanic belt, the southwest Pacific and its subregions which border our areas. The southwest Pacific shows a weak 29 and 13 year periodicity of volcanoes in eruption over that period and the Kermadec-Tonga-Fiji basin shows a 21 year periodicity (Michael 1973). More importantly, Figure 4 implies that island shores are likely to be frequently impacted by the arrival of drift pulses, a point that will be discussed in a succeeding section, and that factors geographically external to the region do influence islands within the local area.
II. PHYSICAL FACTORS OF THE SEA

SEA LEVEL CHANGE AND SMALL ISLANDS

Perhaps the most severe environmental change experienced by all small islands has been the rise in sea level over the past 18,000 years. This is due to the melting of the massive Laurentide and Fennoscandian ice sheets in the northern hemisphere. The implications of this positive change in sea level in terms of island biogeography and ecology are not yet fully understood. The effects of this change include changes in island size, shape, nature, and distribution.

Changes in Island Distribution, Size, and Type

At the height of the maximum glaciation, the area of land was much more extensive than today. Figure 5 sketches the present distribution and extent of islands compared with 18,000 years ago. It shows that not only were more present day islands united to form larger land masses, but also that many new islands were formed. At that time, at least 50 islands of varying sizes would have been found in the Melanesian border plateau between 10°S-10°S, 175°E-175°W, where there are now only four isolated groups, Niulakita, Rotuma, Fatuma, and Vailis. Some of the islands of this now submerged archipelago were of large size; the Bayonaisa fog instance would have covered at least 350 km², while the Tuscarora, Bobbie, Kosciusko, and Fuguen 'islands' would have been only slightly smaller. Collectively these and other islands would have provided a series of stepping stones linking Tuvalu to Fiji in the south and Samoa in the east. Based on present day depths many of these islands would have been extant up to 10,000 years ago and only become extinct in the following two or three millennia.

In addition to the total loss of many islands, others were greatly reduced in size. Figure 6 compares the land areas in south central Lau 18,000 years ago, 10,000 years ago and at present, and graphically illustrates this point. Up to 10,000 years ago Lakeba would have covered about 150 km²; it now covers 56 km². Initially Quoqa would have occupied about 100 km²; it is now less than five per cent of the original area. At the present the largest land mass in south central Lau would have been located less than 15 km east of Lakeba and would have covered an area of about 1,200 km²; it is now the Argo lagoon and reef complex whose rim is just awash at low water. In these instances large horizontal shifts in the position of the land-sea interface are indicated. But not all land masses were so reduced in area. On some islands the rise in sea level was registered more in a vertical sense; Kabara for instance would have covered very much the same area at glacial maximum times as it does today. Clearly then, the local, on-site effects of the sea level rise were highly variable and depended very much on the nature of initial slopes and morphology.

Two other points are worth noting. On some islands the 100 m rise in sea level and its subsequent levelling off a few thousand years ago resulted in a change in island type. At glacial maximum times, the islands of the southern Gilberts and Tuvalu would have been low limestone features possessing a very hard and rough karstic surface topography surrounded by a steeply cliffed, essentially beachless, rocky shoreline - not greatly different from present day Nauru and Osam island and most of Kabara. Now, the dry land area of these islands is totally different. The atoll motu and reef islands of the southern Gilberts and Tuvalu are composed almost exclusively of loose sand and gravel deposits that reach less than 5 m above mean sea level. So subaerially exposed outcrops of the initial karstic surface have been reported from these islands. As elsewhere flooding of the original surface also greatly reduced the amount of dry land. Thus the atolls of Fanimafati and Nukunualae would initially have covered dry land areas of about 270 km² and 65 km², respectively, whereas now the total area of dry land in both cases is less than three km². Tiny Nukalaka, the southernmost of the coral islands, now covers an area of only 40 hectares of land but would have been about 250 km² at glacial maximum times.

Second, on some of the limestone and/or volcanic islands south of Nukalaka, the Tranquillising sea brought with it a change in the relative proportions of dryland terrrain types. For instance, Lakeba, which is now basically a volcanic island with only a small outcrop of ancient limestone on its western and southern coasts, would have had a much greater amount of limestone terrain, particularly in the east. Judging from the present day lagoon, the whole of the eastern half of Lakeba at least until 10,000 years ago would have been covered by a low karstic limestone salient of dry land extending some 6 km seaward of the present island shoreline. It is therefore very clear that islands have assumed their present basic sizes and shapes only very recently and that adjustments to this massive rise in sea level are still taking place at the land-sea interface.

Sea Level, Island Landforms, and Land Cover

It is worth noting that the Flandrian transgression is but the most recent major shift in sea level, and that throughout the Quaternary sea level has swung repeatedly above and below its present level in response to ice-volume changes in high latitudes. Such fluctuations can be considered of great importance in the development of small island landforms. Indeed, perhaps one of the major differences between small islands and larger land masses is their rapid response to changes in sea level. This results from a combination of factors: all island drainage basins are essentially coastal; they are of small area, frequently about the same size, and most possess a low stream order network. On Lakeba, an island of 36 km², there are more than 25 separate stream catchments arranged...
radially around the island, the greatest horizontal distance between catchment head and outlet being less than 4 km. Small island basins, geographically closer to their ultimate base level—sea level—than are large island catchments. Multiple local base levels, a feature of a topography on a continental scale, are rare on small islands. It is these characteristics which make a small island catchment quickly responsive to any shift in sea level. A fall in sea level would trigger stream downcutting and hill-slope retreat, catchments which would quickly percolate up through the drainage network. Any marine or alluvial deposits developed in sympathy with the prior high sea level would be rapidly eroded and the resulting sediment dispersed to the sea, particularly during episodes of high intensity rainfall. A model of small island development

The survival of raft coastal and fluvial landforms so common on large land masses is therefore unlikely on small islands. Conversely, a rise in the level of the sea would flood the lower end of valleys, impede sediment movement and reduce catchment erosion. If the sea were to stabilize at a new higher level, infilling and valley infilling would be enhanced. Clearly this simple model of small island catchment development, which sees sea level as the fundamental control, is an oversimplification; it assumes, for instance, no tectonic movement. Yet clearly it is restricted to islands possessing subaerial drainage systems and therefore is not applicable to the coral or limestone islands. But for the volcanic or primary volcanic islands of the area, such as Lakea and Koro, it may summarize their development over the last 100,000 years, that is since the last inter-glacial. In this model the problematical valley swamps are seen essentially as recent features developed during the waning stages of the Flandrian transgression and the subsequent stabilization of sea level about its present position. Local cover

Major shifts in sea level like the Flandrian transgression are also of great importance to the land cover of small islands, and hence the greater part of the corals which cover small island ecosystems. It is quite obvious that islands completely submerged by the sea level rise during the last interglacial fauna and flora have been drowned. Others such as all the southern Gilbert and Tuvalu reef islands and atoll motu which have been built only in the last few millennia, since the transgression terminated, clearly possess an extremely recent land cover. By the way of contrast, islands at higher elevations, emergent throughout the transgression but reduced in size, would have retained at least some of the continuous vegetation of the first stages of the marine transgression. We might expect islands to have rather impoverished plant cover with few if any endemic species. Unable to take advantage of climatic differences, we might anticipate that sea level change alone would have a major role influencing the spectacular differences in terrestrial biomass between the northern reef islands and the central and southern volcanic and limestone islands.

RECENT SEA LEVEL HISTORY

While the massive rise in the level of the sea since the maximum of the last glacialiation is universally acknowledged, there is little agreement as to when this transgressing sea first attained its present position in the Holocene. Nor is there agreement as to the magnitude of the rise in sea level over this century since that time. Thus there is even conflict as to whether the most significant recent change at the land-sea interface has been a fall or rise in sea level. In some areas there is evidence that the sea first reached its present level (3 m) 10-15 years ago, others 2-3000 years ago, and in others more recently still. Some have argued that sea level in the Holocene has risen about its present position and then fallen; others that it has never been higher in the Holocene than at present.

To go outside our region in search of the historical record of the movement of the land-sea interface, especially the Holocene, we find that there are a number of studies which bear on this topic. Detailed records of sea level over the last 2000 years or so are available from Senegal, the east coast of Africa, the American coast east of the Rockies, and the British Isles. The general evidence indicates that sea level has been relatively constant, at least within the last 2000 years. Clearly this has enabled some sort of stability to be achieved between internal island adjustments and the external factor on sea level. However, it has been highly variable among and between different geographical regions and island groups because of the effects of changes in ocean currents and water temperatures. In the tropical Pacific the oceanic and sea level variations in the oceanographic and meteorological parameters of wind, direct atmospheric pressure and air temperatures create a complex interplay of sea level fluctuations. The effect of sea level changes is to alter the amount of water on and off the island, thus affecting the amount of fresh water available for use by the local population. This can have significant effects on the economy of the island, particularly in areas where water is scarce. In some cases, the increase in sea level can lead to the flooding of low-lying areas, forcing communities to relocate. The effects of sea level change on coral reefs and marine ecosystems are also significant, as the increase in sea level can lead to the loss of habitat for many species.

Spatial and temporal variability in sea level

The apparent sea level trends of the past several decades result from glacio-eustatic, tectonic, and both climatological and oceanographical processes. The relationship between climate and sea level has been studied extensively, with a focus on the response of the Earth's oceans to changes in climate. This relationship is complex and influenced by a number of factors, including the melting of glaciers and ice sheets, changes in ocean circulation, and the expansion and contraction of the Earth's water volume. The melting of glaciers and ice sheets is a major factor in the rise of sea level, as the Earth's water is redistributed from the land to the oceans. Changes in ocean circulation can also affect sea level, as changes in the circulation of the oceans can lead to changes in the distribution of heat and salt, which in turn can affect the density of ocean water and sea level. The response of the Earth's oceans to changes in climate is also influenced by the expansion and contraction of the Earth's water volume. This expansion and contraction is influenced by changes in the Earth's temperature, as water expands when it is heated and contracts when it is cooled. The relationship between climate and sea level is therefore complex and influenced by a number of factors, including the melting of glaciers and ice sheets, changes in ocean circulation, and the expansion and contraction of the Earth's water volume.
been developed by similar processes. These processes are continuing to this day: wave deposition and wave erosion resulting in the rectification of shorelines and changes in island configuration.

**Regional wave climate**

Details of wave climate in open ocean situations away from continental margins are not well known. Nevertheless, enough is known about the pattern and nature of wave generation and propagation in the Pacific to describe the salient elements of the regional wave climate. Four major types of waves are present in tropical latitudes around the dateline (Fig. 7). These are the easterly trade waves, southern swell, northern swell and westerly storm waves, whose relative importance varies temporally, particularly on a seasonal basis. Of these the easterly trade waves are the most persistent; they may be present all year round and are dominant during the winter months. Generated by the trade winds which blow over great distances to the east of the region, the easterly waves give a strong windward-leeward effect on island shorelines, reefs and adjacent seas. Some seasonal variations in the magnitude of trade wave energy can be expected to accompany seasonal changes in trade wind strength and area covered by the waves. Likewise, wave direction may vary latitudinally from north-east through east to southeast moving southwards along the dateline in sympathy with the seasonal pattern in wind direction. Nevertheless, because the region is down-sea from the core of the trade wind belt, waves from an easterly quarter are likely to prevail during most of the year in the open seas surrounding islands. It is also likely that over long periods the average total trade wave energy exceeds that of other wave types, a conclusion based on a Hawaiian study (Chinads 1972) that may have wider applicability.

A second wave type, the westerly storm waves, occurs infrequently during the summer, generally between November and March, when the trade winds are weakest. These westerly waves are associated with local fronts and low pressure cells in the summer monsoon and are accompanied by strong winds and high rainfall. On occasion westerly seas can be particularly fierce, though generally short lived and may be mitigated by hurricane waves.

**Distant storm waves**

In contrast to such locally produced storm waves which are developed in distant storms, far to the south and east, the waves pass out of their area of generation and reach low latitudes as swell waves. Sometimes northern swell reaches into the southern hemisphere from the North Pacific. These waves associated with low pressure areas at high and mid-latitudes in the North Pacific arrive episodically during the summer from October through May and approach the region from the north or east. One example of heavy swell originating in the North Pacific which caused damage in the South Pacific occurred in December 1969. A depression centred about 45°N 175°E with a central pressure of 960 mb and maximum wind of 50-60 knots, generated a long period (25 sec) northerly swell of high waves (13 m) which fanned out southwards and was experienced up to 6000 km away (Matthews 1971). The waves took three days to reach the equator and five to reach Fiji. Heavy swell was reported over a large area from Hawaii to Fiji and considerable damage was done to coastal installations in the Tuamotu Archipelago. High northerly swell were observed at Arorae in the southern Gilberts, at Nukunonu, Funafuti and Bluaikita in Tuvalu and in the Yasawa in northeast Fiji. Predicted swell heights declined as the waves moved southwards through the region from 4.7 m at Baru (G. Gilberts) to 4.0 m at Yasawa-i-Rara (Fijis). More regular in occurrence and present especially during the winter is the southern swell generated by strong winds in the 'searing forties' and 'fighting fifties' of the southern oceans. These waves have been tracked right across the Pacific by Munk et al. (1963) and Shoemaker et al. (1966) who determined the generating storms south of Australia and in the southern Indian Ocean. To reach Fiji, Tuvalu and the Gilberts such waves must pass through the Tasman Sea 'window' between Australia and New Zealand. Such a great circle path means the waves will generally strike the islands on their southern sides. One example of southern swell reaching Fiji occurred in October 1977 when Swells up to 6 m high were reported along the southern coast of Vanuatu.

The directional components of regional wave climate have been highlighted in the foregoing paragraphs. This has brought the distinguishing feature of small islands, and certainly a major contrast with continental coasts, to the fore since the former have the potential to be impacted by waves arriving from all points of the compass. Depending on the direction and magnitude of incident waves, islands can have rough seaward and calm landward sides which can be geographically displaced around an island because of wave approach direction. Island shorelines and coastal ecosystems must therefore adjust to the long term summation of relative wave power both in a temporal sense and spatially around an island. Roberts (1974) has shown how mean wave power varies around Bikini atoll, Marshall Islands and Great Cayman in the Caribbean, and how the distribution of some features of shore geometry, wave structure and littoral biota conform to this pattern. He argues that the spatial distribution in wave activity is controlled by prevailing waves generated in the trade wind belts. There is field evidence to suggest that a similar situation exists for islands in the reference area where the easterly trades provide the prevailing background waves throughout the region. It is also clear, however, that there are spatial-temporal variations in sea conditions. These are reflected, for example, in the seasonal shift of ocean fishing activities from western to eastern grounds in winter and summer respectively as an adjustment to the seasonal shift in the location of rough and calm seas. Moreover, our analysis has suggested that heavy swell from the north and south can on occasion disrupt the wave condition and cause considerable disturbance to coastal ecosystems.

**Tsunami and hurricane waves**

Two other components of the regional wave climate should briefly be mentioned: tsunami and hurricane waves. In common with other islands throughout the Pacific, but within the region are vulnerable to tsunamis (seismic sea waves) generated in the circum-Pacific tsunami area (Fig. 7). Reports on the occurrence of tsunamis in the region are meagre: the preliminary catalogue of tsunamis occurring in the Pacific Ocean (Ida, 1966) lists 20 tsunamis that reached Samoa between 1837 and 1966 from seismic events off Oahu, Hawaii, the Marquesas and the New Hebrides. It also reports five tsunamis generated from centres within or close to the region: 1865 (Tonga); 1917
Spatial and temporal variability

Spatial and temporal variability

III. PHYSICAL FACTORS OF THE ATMOSPHERE

WIND

Of the external controls on island ecosystems, those associated with the atmosphere are the most obvious and best documented. In addition to generating ocean waves and driving ocean currents, wind is important to island biota by maintaining relatively high levels of evapotranspiration and by concentrations of sea spray salts. It also has a mechanical effect on plant growth form and of sufficient density damage breakage and uprooting of crops and trees.

Spatial variations

The southeast trades dominate the regional wind regime and result in consistent windward (eastern) and leeward (western) sides on most islands irrespective of their size and topography; the eastern half of Samoan Island and eastern and islands of Fiji are especially vulnerable to tsunami of local origin, particularly from the Suva-Bau seismic zone and Tonga trench. All islands in the region are vulnerable to tsunamis from distant sources, and as with ocean waves and swell they can be impacted from any direction.

The effects of tsunamis on local island ecosystems are not known. One problem that Richmond (1977) found in Fiji was that there was no written record of tsunamis nor any reference to them in legends and dances. He notes that one reason for this is probably that most people simply did not know what tsunamis were and took any unusual waves as due to distant storms.

The effects of hurricanes waves and surges on island ecosystems are rather better known. Later in this section the spatial and temporal patterns of hurricane activity within the region are examined in detail. For the moment it is only necessary to note that seas generated by hurricane both from within and outside the region can reach island shores. If littoral ecosystems are adjusted to the normal long-term wave regime as described, then hurricane waves are capable of randomly interrupting this condition and causing irreversible changes, particularly topographical changes.

The contemporary physical factors of the sea, hurricane waves are potentially the most catastrophic. The potential is illustrated by the effect of Hurricane Bebe on Penumati atoll in 1972 (Baines, Beveridge and Maragos 1974).

Figure 13.1: Isolines of mean wind direction and velocity over the holiday, [data not provided, diagram not visible].
Spatial and temporal variability

In addition to spatial differences, there are important temporal variations in the wind direction, strength at seasonal, interannual and longer time scales. These result from the region's straddling of monsoon and intertropical boundaries; thus small seasonal and/or meridional shifts in the doldrums or trades bring with them large variations in wind (and rainfall). A seasonal cycle is clearly depicted on the chart of mean monthly wind strength and direction (Fig. 8). It demonstrates the latitudinal shift in the trades and that these winds are strongest and most widespread during winter. It is also clear that in the northern part of the region surface winds change from easterly in winter to northeasterly (NE) in summer, the latter bringing what Runge (1970) describes as monsoonal 'summer' weather. Clearly, the mean monthly patterns on Figure 8 mask a longer-term and seasonal variation and it is apparent from the bimonthly wind charts for the period 1950 to 1972 (Buwalda and Nijems 1973) that such variations are of large magnitude. Also, the mean conditions appear to underestimate the strength and importance of the northwestlies and westerlies, especially in the north. Wetter winds are considerably stronger than the easterlies and are often equally strong and very persistent. At Funafuti almost all gales are from the west, and on occasion they have caused damage commensurate with that of tropical storms and hurricanes.

Throughout the region and especially in the north, the rainy and easterly seasons are recognized; one traditional adjustment in Tuvalu is the seasonal shift of canoe activities, and sometimes villages, from one side of an island or atoll to the other to take advantage of the most favorable environmental conditions. On Tarawa in the Gilberts the year is divided into two seasons: the rainy season from November to March and the December to February period is characterized by easterly winds, squalls and irregular currents; Aneitymu brings more steady conditions with trade winds from the east, less rain and regular currents (Lawrence 1977). In the central and southern islands, including eastern Fiji, wind-seasons are also acknowledged though there the wettest period is better known as the hurry season. We should also note that throughout the region the onset of the wet season is extremely variable, both in time and space; likewise its severity and length. On occasions it is totally suppressed and the trades or easterlies continue throughout the year.

The annual cycle of two contrasting wind seasons thus appears to be the loss due to interannual and longer meridional fluctuations (Wyrtki and Meyers 1975b) have described the variation in the tropical Pacific for the period 1950-72 and points out the most striking anomalies. From their narrative it is clear that interannual and longer variations near the dateline are of a magnitude at least equal to that of the annual, two season, rhythm. It is also clear that there is a connection between wind direction, strength and area on the one hand, and both oceanographic and other climatic variables, notably sea surface temperature, cloudiness and rainfall, on the other.

RIMFALL

Freshwater has a fundamental role in the functioning of small island ecosystems. For island populations too much or too little rain is a frequent problem, particularly the latter. One of the features of most small islands is the lack of natural surface water in the form of fresh water lakes, ponds or even permanent streams. The previous nature of these substrates on coral sand and limestone islands and the smallness and steepness of stream catchments on volcanic islands ensures a rapid throughput of rainfall that arrives at the surface. Vegetation cover and soil impede this movement, and they clearly utilize the available moisture. Few studies have been made of the water balance of whole small islands in the tropical. Water scarcity or an excess of water supply measures are based on the concerns of the water balance, the difference between the input of water in the form of precipitation, the loss due to evaporation and transpiration by plants (evapotranspiration) and changes in storage (soil moisture, groundwater, streams, etc.).

Here is an evident from Figure 9 that one of the locations where the boundaries between the above zones meet is in our reference area. A steep latitudinal gradient in mean totals can therefore be expected. Of equal or greater importance, it can be anticipated that slight coastal or meridional shifts in the rainfall belts will produce large temporal variations in the amounts of local rainfall.

Figure 10 shows the pronounced latitudinal gradient from very dry through very wet to moderate rainfall moving south from the equator. Tamana in the southern Gilberts is the driest island with an annual mean of 113 cm, Rotuma the wettest with 164 cm, while Lakeba in southern Lau with 190 cm is representative of a moderate rainfall station. Suvla on the same latitude as Lakeba is also shown; its higher rainfall total (302 cm) illustrates the local effects of a much larger and higher land mass. Extreme rainfall ranges are large: the lowest annual total (15.6 cm) was recorded at Franka and the highest (873.2 cm) at Funafuti. These two stations are only 7 km apart. These falls occurred in 1950 and 1940 respectively, the first being a widespread dry year through the central south Pacific, the second a widespread wet year. The minimum and maximum annual totals for each station shown in Figure 10 again demonstrate a zonal pattern. It can be noted, moreover, that annual maxima for islands in the dry and moderate rainfall belts are less than the annual average of islands in the wet zone. Similarly, wet zones may have a greater number of drier years in the central and western parts of the region.

Throughout the region, as in many of the drier areas, the rainfall distribution is strongly related to the presence or absence of monsoonal activity. The latitudinal gradient is most apparent in the islands in the north, and it is least in the central and southern regions. In the southern region, the rainfall is more strongly related to the presence or absence of easterly winds.
within each zone there is marked variation in annual rainfall totals. At Onotoa extreme range from 18.6 to 239.7 cm, at Punaqitid 5.4 to 673.2 cm, and at Lakeka 76.9 to 294.6 cm. These ranges suggest that one important feature of the climatology of the islands throughout the region is high variability of rainfall through time.

**Temporal variability**

Variability can be expressed in a number of ways, one being a simple index where per cent variability is the mean deviation from the average divided by the average and multiplied by 100. Values for each station plotted against latitude are given in Figure 10. Dry zone stations show on average as having a particularly high variability, 30-35 per cent, figures that are similar to those along the desert margins of continents. On the other hand, wet zone stations have a low average variability (13 per cent) and moderate zone stations intermediate variability, around 20 per cent.

This index indicates average variability and, although the spatial patterns that emerge are clear enough, it does need supplementing with other indicators. Annual differences from one year to the next can be large. Onotoa in the dry belt had only 39 cm in 1976 and over four times that amount (183 cm) in the following year; Lakeka in the medium rainfall belt had 150 cm in 1953 and nearly double that amount (291 cm) in 1956; while Punaqitid in the wet zone had 673 cm in 1940 and less than half that quantity (219 cm) the following year. Interannual fluctuations of these magnitudes must have repercussions for the operation of island ecosystems.

**Short-term cycles**

While it is not being suggested that there is a regular wet-year-dry-year cycle (mean annual totals are but a crude indicator of short term variations), these figures serve to illustrate the fact that the region’s climate is punctuated by periodic dry spells and/or wet spells which can extend over a number of months. Plots of monthly rainfall for the period 1962-67 for Beni in the southern Gilberts and Nauru (Northern Tuvalu) (Fig. 11), highlight this fact. These stations have been selected for a number of reasons. Firstly they are representative of islands in the equatorial dry belt around the dateline; secondly it is in this region that rainfall variability is greatest; thirdly, the causes of the variations appear relatively well known. The specific time period was selected to correlate with a time period of surface winds and sea surface temperature observations at Canton Island, Phoenix Group, investigated by Bjerke (1972). Bjerke showed that the major changes in sea surface temperature of the central and eastern equatorial Pacific are caused by the varying strengths of the easterly winds and inherent variation in upperwelling. He illustrates feedback effects of ocean temperature variations upon the atmosphere such that in the cool ocean case the atmosphere has a pronounced stable layer between 900 and 800 mb which prevents convective rainfall, whereas in the warm ocean case the heat supply from the ocean eliminates atmospheric stability and activates heavy rainfall. The succession of zonal wind speed and sea surface temperatures at Canton Island is plotted in Figure 11, along with monthly rainfall values for Beni and Nauru, some 1500 km to the west of Canton Island. The correspondence between periods of low winds, high sea temperatures on the one hand, and high winds, low sea temperatures and low rainfall on the other, is clearly depicted. This example serves to illustrate the nature of the interactions among some of the external controls of island ecosystems, and the manner in which such external factors may affect rainfall over the long term. It also highlights the amplitude of rainfall fluctuations over a not-atypical six year period: thus at Beni rainfall for a four month period November-February, 1979 was only 2.66 cm, whereas for the equivalent months a year later the total was 176.58 cm, or eighty times greater.

**Longer period variability**

In addition to such relatively short term fluctuations are longer period variations. Dry spells and wet spells may last several years in succession. At Punaqitid annual rainfall figures for 1938-40 were 521, 531 and 673 cm and a decade later, 1949-51, were only 261, 261 and 260 cm. At Beni a three-year wet period (1951-53) with annual totals of 156, 115 and 136 cm was followed by a three-year drought (1954-56) during which time only 115 cm of rainfall was reported, made up of annual totals of 31, 39 and 65 cm. The contrast between a wet zone and dry zone station is clear from these figures but together they highlight the persistence of low and high rainfall regimes. Unpredictable droughts of this duration must seriously affect the functioning of island ecosystems by depriving them of input rainfall for a prolonged period. Regrettably, rainfall records throughout the region are not of sufficient length to establish such return periods but there is evidence of sustained droughts in the southern Gilberts and Tuvalu in the 1870s, 1890s, mid 1920s, late 1930s and early 1950s and in Lakeka between 1939-41.

Thus far we have established the existence of large annual, biennial and triennial fluctuations in rainfall. These feed into lower frequency variations. Stoddart and Walsh (1973) identify a particularly strong 5.3 year cycle for 10 central Pacific stations, though stations with longer records such as Punaqitid also show significant cycles in the range of 12-30 years. Their research on records for Fiji, Western Samoa and Rarotonga indicated even longer period tendencies and lead them to suggest the presence of 100-150 year rainfall epochs. In the last 150 years: very dry (early 20th century) high rainfall (1930-35) and intermediate rainfall (1940-present).

**Tropical storms and hurricanes**

Tropical storms and hurricanes are perhaps the most important catastrophic events having a regular impact on small island ecosystems in the tropics. In a very short time they initiate dramatic temporary and permanent changes in components of physical and biological environ-
Spatial and temporal variability

While such extreme weather events are part and parcel of the climate of much of the tropical world, it is important to recognize that hurricanes are not experienced equally throughout the tropics. Instead there are significant geographical variations: the southwest Pacific, east of the Tuamotus, is not affected. Likewise the Line Islands, Phoenix Group and Gilberts are regarded as hurricane-free islands, being located north of the South Pacific’s hurricane belt. Hurricane tracks for the decade 1959-69 (Figure 12) indicate that most originate in the region between 10° and 15°S and from 150°E to 175°W. This region produces an average of seven tropical cyclones per year, or 11 per cent of the global total (Kaur 1971).

Around the dateline there is a latitudinal gradient in cyclone incidence. Figure 13 depicts the mean number of hurricanes per decade for a thirty year period (1949-69) plotted for each degree of latitude. Three zones are clearly distinguished. First is the hurricane-free zone north of 8°S which includes northern Tuvalu and the southern Gilberts. The second zone from 8° to 16°S shows a steady increase in cyclone frequency in a southerly direction – the islands of southern Tuvalu, Rotuma, Wallis and Futuna fall in this latitudinal band. Cyclones are more frequent in the third zone south of 16°S where on average about 12 cyclones per decade are experienced; this zone includes all the Fiji Group.

Variableity of cyclone incidence

Figure 13 also shows the decadal ranges in cyclone frequency by latitude. These suggest that there is little decadal variation in cyclone occurrence at each latitude step in the central area between 11° and 15°S, but that in the southern zone the three-decade mean is not a particularly good indicator of decadal frequency, the extreme range being from 7 per decade to 18 per decade. A further point, missed in Figure 13, should be noted: the raw data suggest a medium term latitudinal shift in frequency. Peak frequencies occurred in the area between 13°-19°S in the 1950s but between 20°-25°S in the 1960s. Also of note is the fact that hurricane induced effects can extend well beyond a cyclone’s path and into areas where fully developed hurricanes in close proximity are extremely rare. On low coral islands, high seas or gale force winds, or both, generated by hurricanes some hundreds of kilometres away have occasionally swept the islands with destructive effects. The radius of gale force winds associated with some tropical cyclones can be as much as 800 km. Strong winds and torrential rainfall associated with a cyclone at the end of January 1966, for example, caused a great amount of damage in the Tokelau although the centre was never closer than 600 km. On one island, Makomono, waves swept continually over the inhabited island for seven hours; coconut and breadfruit trees were badly affected by strong salt-laden winds (Kaur 1976). Large storms to the south of the hurricane-free belt, particularly those that are slow moving and have a strong and sustained west to east direction, are those more likely to funnel high seas into the hurricane free area of the southern Gilberts and northern Tuvalu.

Nonetheless the combined possibilities of slight latitudinal shifts in cyclone frequencies and hurricane effects extending into low latitudes, the zonal pattern of contemporary occurrence given in Figure 13 is clear. It is thus likely that island ecosystems and particularly island structures will differ spatially depending on whether they are located in areas of hurricane absence, low incidence or high incidence. The quite independent latitudinal contrasts in island types, from low coral to high limestone and volcanic islands make it difficult, however, to adequately test such a hypothesis in this area.

In the long run all islands within each latitudinal zone have an equal chance of being struck by a severe hurricane and of experiencing less severe storms more frequently. Inevitably there is immense spatial variation in the impact of a single storm depending on its size, intensity, track and timing relative to tide levels. In general the degree of impact decreases away from the storm centre and is at a maximum in the front left quadrant (looking in the direction of movement) where the most severe wind velocities occur. The most obvious feature of the cyclone tracks shown on Figure 12 is their consistent northerly course from north to south. Less clear is the east-west pattern. Data from the south Pacific for the 1939-69 period (Kaur 1976) indicate that for five degrees squares the point of axis is generally to the east of the point of entry; 68 per cent of cyclones followed an easterly or south-easterly course and 32 per cent moved westerly or south-westerly. Thus on average it is likely that the northern and western sides of islands will be more affected by hurricanes than the southern and eastern sides. The unpredictable nature of hurricane movements and the fact that storms are revolving does, however, make all sides of islands vulnerable.

Temporal variations

In addition to geographical variations in hurricane incidence there are apparent, if not easily quantified, temporal variations, the most obvious being at the seasonal scale. The hurricane season extends over six months, November through April. The following figures give the percentage of storms per month in the south Pacific for a 30 year period (1939-69) and for the eastern islands of Fiji for the last century (1875-1975) in brackets. November: 4 (4); December: 13 (17); January: 24 (20); February: 27 (22); March: 23 (20); April
9 (9). These figures indicate maximum activity in January, February and March with no one month clearly dominant. They also suggest that the season begins gradually and more abruptly. However, Kerr (1976) found an increase in frequency of early season storms in the 1960s compared to previous decades; the number of November and December events in the 1960s was double that of the 1930s. Activity should be much greater if hurricanes occur outside the recognized season. A particularly severe storm, 'Hebe', passed over Tuvalu in 1957, and an unnamed cyclone passed near Lakeba in May 1957. Ward (1975) suggests that sea surface temperature measurements made in November and December may give some indication of hurricane activity for the remainder of the season.

Inter-annual variation
Inter-annual variation in hurricane frequency is large. In the south Pacific storm belt the average number of tropical cyclones during the period 1939-69 was 6.5 per year with a range from 3 to 12 (Kerr 1976). The 1971/72 hurricane season was one of the most active in recent times. There were no fewer than ten severe storms and hurricanes compared with only one severe storm and no hurricanes in Tuvalu. Furthermore, there were no hurricanes in any one area within the storm belt also show great year to year variation. For instance, in the eastern islands, the year 1971/72 was a quiet year, while 1972/73 was equally quiet. Second, it may be that events such as those occurred in the 1880s, are now considered uncommon. Both points in fact may be correct. In contrast to Tuvalu, about 80 storms have passed through the eastern islands of Fiji in the last one hundred years. The time-distribution of these events (Fig. 14) shows the clustering of storm periods separated by storm-free intervals, the most recent cluster of hurricanes occurring in 1972-75 (Hurricanes Bebe, Juliette, Lottie and Val).

Ward (1975) suggested the existence of a quasi-four year cycle in hurricane activity in the south Pacific, based on 26 years data. While far more storms occur in Tuvalu in the 1960s than in the 1950s, it is possible that in both decades the number of hurricanes has not been attempted, a similar periodicity may be present. A lower frequency cycle may also be suggested by decadal variations. The 1880s, 1900s and 1950s had a relatively large number of cyclones, while the 1930s and 1940s had relatively few. No general trend of increase or decrease in frequency through the last one hundred years is apparent, although for the south Pacific as a whole Kerr (1976) has indicated that the averages for the last three decades were 5.8 (1940s), 6.4 (1950s) and 7.2 (1960s). He suggests this trend toward a higher frequency is probably accounted for by improvements in the capability to detect cyclones in later years.

Intensity and affect of storms
Two further points should be made. Tropical storms vary greatly in their size and intensity. Kerr (1976) used 'minor', 'moderate', and 'severe' to describe the magnitude of the storms' impact on the island group concerned, as well as the personnel and the workers. The absolute intensity of the meteorological event. Although subjective, this is the most commonly used scale when considering island ecosystems. Based on such estimates for the 30 year period (1939-69) for the Fiji Islands, about one storm in five can be classified as 'severe', one in four as 'moderate' and the remainder 'minor'. Thus in the last century the Fiji Islands may have experienced 20-30 severe hurricanes.

Second, the low frequency of storm events in low latitudes does not mean that the ecological effects are any less severe than in areas of higher cyclone frequency. Indeed, it can be argued that the massive changes to reef and island landforms and biota at Funafuti during 'Hebe' in 1957 were not the result of the intensity of that particular event but also a result of the long-term lag between it and any predecessor. In areas of more frequent hurricane activity, however, where time lags between events are shorter, island ecosystems may well be more adjusted to periodic high magnitude perturbations. Thus it is likely that the at-Island effects of a single storm of equal magnitude experienced on like islands, but one in an area of low storm frequency and one in an area of high storm frequency, could be quite different. It is also germane to point out that the term 'hurricane absence', 'low frequency' and 'high frequency' were used to delimit latitudinal regions of hurricane activity, as relative. If the spatio-temporal patterns of hurricane occurrence over the past several decades are representative of the past several thousand years, since sea level first stabilized around its present position in the Holocene, then the Fiji Islands may have experienced some 5000 storms and Tuvalu in the zone of low frequency some 500 storms. Perhaps when considering island ecosystems this is the perspective one should adopt.

IV. EXTERNAL FACTORS IN TIME AND SPACE AND ISLAND ECOSYSTEMS

In this section it has been demonstrated that small tropical islands are subject to an array of external factors which are highly variable in time and space; they operate on time scales ranging from the geological to the instantaneous, and spatial scales from all islands to parts of a single island. It has been argued that the lithologic, oceanographic and climatic elements identified at least some of the physical limits within which all island ecosystems (and by implication human use systems) operate; they are the most essential and pervasive components of the island ecosystem and at the same time its general environment. As far as the system is concerned, these have also been implied that these components, when viewed as variable inputs to the insular ecosystem, are of such a magnitude that their fluctuations must have serious implications for both the structural organization of the systems and the processes at work. This concluding section lists some of the salient facts which have emerged from the analysis thus far, reviews some of the implications for the stability of the island ecosystem, explores some of the analogies between natural event systems and human use systems, and finally draws some conclusions about the spatio-temporal physical variability relevant to the rational use of island ecosystems.

Review
Any study of the development and dynamics of island ecosystems in this part of the tropical Pacific must take into account five main groups of facts.
Spatial and temporal variability

The location and distribution of islands has not been static but has varied over recent geological time as a result of the combined effects of horizontal and vertical movements of the earth's crust and repeated swings in the level of the sea. The regional plate tectonics and the overall evolution of the ocean basin and its component basins and move- ment on slopes. Hurricanes and storms have on occasions lodged sediment well above the level of the sea. The actions of man have built up coastal deposits; and on other occasions they have eroded hill slope deposits and cut back shallow coastlines. The first case the terrestrial extent of islands has been enlarged; in the second it has been reduced. In addition to such brief catastrophic local impacts are more pervasive changes like those associated with the contemporary global rise in sea level.

Variability of climatic-oceanographic regimes

Strong latitudinal contrasts in island types have been identified notably between the low coral reef islands and atoll motu in the north and the variable array of volcanic and/or limestone islands in the south. We have also identified steep latitudinal gradients in rainfall incidence from dry through very wet to moderately, in hurricane activity from absence through low to medium to high frequency, and, less clearly in wind and wave regimes. In the first case the terrestrial extent of single elements into zonal regions, it is clear that the elemental latitudinal boundary is not always concordant. Nor are they static. On the geological time scale the focus of volcanic activity and sea-level change has shifted latitudinally through a few degrees, and meridionally. In historic times significant shifts in the zonal climatic and oceanographic belts have occurred and boundaries have expanded and contracted. Because there are pronounced environmental differences over quite short distances even small lat- itudinal shifts in these belts or their boundaries result in major change in environmental conditions. Put another way, islands are effectively moved to and fro, along a north-south time, from one climatic-oceanographic regime to another, via-avis their mean position.

Annual versus inter-annual fluctuations

Substantial temporal variations in physical inputs at a whole range of time scales have also been identified. On the geological time scale, episodes of volcanic activity 9-6 million years ago and 3-4 million years ago have been reported, while in the last 70 years pulses of volcanic activity in the southwest Pacific show a weak 13 and 29 year periodicity. Sea-level rise and fall, and phase and sea-level has repeatedly swung below and above its present level in oscillatory fashion. In this century, there has been an apparent secular rise in sea level. Though there are suggestions of possible secular trends and/or periodicities in some of the other oceanographic and climate fac- tors records are on the whole inadequate to identify them with any degree of certainty much beyond the high frequency annual cycle. Wind, rainfall, hurricanes and sea state do show an annual cycle of two contrasting seasonal but there is great year to year variation; on occasions the seasonal signal is weak. The annual cycle appears to be superimposed on interannual and longer term fluctuations. The magnitude of these lower frequency variations is substantial; they are of an order at least equal to that of the annual cycle. Rainfall data in the dry belt suggest a biennial oscillation and throughout the central Pacific a 5.3 year cycle is in- dicated. Drought is thus a frequent and per- sistent feature of the region’s climate. Low- er frequency rainfall cycles in the 12-30 year range have also been identified. For tropical storms and hurricanes in the south- west Pacific a quasi-four year (3-5 year) cycle has been suggested, and this may well be close to the longer, decadal periodicity. But perhaps the key point to stress is simply the magnitude of inter- annual fluctuations; in the last thirty years the number of tropical storms and hurricanes in one season has ranged from one to twelve.

Spatial coherence in environmental variations

Most of the temporal variations at the annual cycle lie within the range in such elements as wind direction and strength, rainfall and hurricane activity as well as sea state, ocean temperature and current strength are spatially coherent; they extend over large areas and include a number of islands or island groups within the region and outside of it. What this means is that we can expect broadly similar environmental conditions, such as drought, to be experienced on adjacent isles at one and the same time. We have also suggested that high correlations exist among a number of the external factors, in one instance between rainfall, cloudiness, wind direction and strength and sea surface temperature, and in another, between hurri- cane activity, intensification potential and sea surface temperature. Though the feed- back of these variables to other processes and spatial relations between ocean-atmosphere and ocean-atmosphere variables are still unknown, in some cases, others are less clear and are the subject of considerable contemporary research activities. What is clear is that the fluctuations in environmental conditions typically affect large contiguous areas simultaneously; they are not confined to localities and tend to the large scale atmospheric and oceanic circulations and only to a minor extent by local circumstances.

Instability of island ecosystems

Attention has been directed towards identifying the characteristics of some external factors which are of significance to the structure and operation of island eco- systems. We have been less concerned with their impact on the system itself, in terms of the actual structural changes wrought by the impact of external adjustments to new 'stable' sea level and the array of external oceanographic and climatic fluctuations we have described. All of the coral islands in the Gilbert Is- lands and Tuvalu, together with their terres- trial flora and fauna, developed less than 5000 years ago; likewise much of the littoral island vector and/or volcanic islands have been expressed in island ecosystems that flow from our analysis.

Inapplicability of the steady state model

It is likely that many of the large scale fluctuations in environmental inputs are modulated or temperature and other mecha- nisms operating within island ecosystems. We must consider that long-lived ecosystems are adjusted to wide interactions in environmental conditions. However it is also obvious that environmental thresholds are regularly exceeded. For components of island ecosystems, the geomorphic landscape, soils and vegetation (as well as for human activities, especi- ally agriculture and fishing) the conse- quences of such exceedence can be profound. More than a decade ago Fouger (1963, p. 5) wrote:

'It is probable that no island ecosystem was ever completely stable. The limited area makes even relatively small changes capable of rather profound general effects; in other words, the buffering effects of great size and diversity are lacking. How- ever, it is likely that, before the advent of man, many, or most of the older island ecosystems had reached such relative stabili- zation that changes were mostly very slow. In most respect organisms present had evolved into an effective equilibrium with their environments. Closed biotic communi- ties had developed that made difficult the gradual invasion or establishment of new species. While the first part of this comment is irrefutable, our analysis of external factors suggests that even 'before the advent of man' island ecosystems were subject to substantial environmental crises, most notably those associated with the final stage of sea-level rise up to about 3000 years ago. In the interval between that time and the entry of man into the area, about 3000 years ago in the eastern islands of Fiji and Tonga and more recently in the islands north of Fiji, natural island ecosystems were rapidly changed in react to rises in sea level. As a result of internal adjustments to new 'stable' sea level and the array of external oceanographic and climatic fluctuations we have described. All of the coral islands in the Gilbert Is- lands and Tuvalu, together with their terres- trial flora and fauna, developed less than 5000 years ago; likewise much of the littoral island vector and/or volcanic islands have been expressed in island ecosystems that flow from our analysis.'
Lakeba and landform and ecological changes caused by hurricane Bebe at Funafuti are two local examples. For island ecosystems in this part of the world, landform stability with or without man's interference is a relative concept; certainly stability is unlikely to be achieved in many places, or for long. Steady state, while it may be a good first approach to contemporary island dynamics, is recently discredited by short and long range factors, which as we have seen, are frequently non-uniform and non-synchronous. Any hypothesis of island ecosystems based on a steady-state is thus a matter of conceptual convenience, which may not bear a close relationship to the total facts. This comment applies equally to island ecosystem dynamics before the arrival of man or subsequent to man's arrival.

The role of man in a larger context

Posberg (1963, p. 5-6) also observed that: It is clear enough that the arrival of man has invariably increased, to some extent, the degree of instability in these systems. With the advent of man, man's increase has frequently assumed catastrophic proportions. The losses in organismic density, population densities, and characteristic biotic communities, which in turn affect the retention capacity, and biotic community organization all amount to an increase in ecosystem instability. In a case of extreme degradation this increase has brought about a high entropy level.

In this context, and in the context of this section, two comments can be made. The 'arrival of man' and his continuous or discontinuous occupation of the island can be viewed simply as another example of an external control. Like the physical factors of the land, sea, and sky, a man's impact on island ecosystems has fluctuated greatly in space and in time. Some changes have been negative, such as airfield construction in a former swamp at Funafuti using fill from borrow pits excavated along the shores of two islands; others have been positive such as the development of the 'tele-siga' in Lakeba and the 'coconut overlay' throughout much of the region. There is a second point that the development of new flora and fauna in an area can be viewed as an increase in entropy as a result of man's activities; such an increase is normal in most biophysical systems. If we plot the time evolution of island ecosystems up to the advent of man in this region, however, it can be argued that the sun total of biological complexity and geomorphologic variety has become progressively greater. Thus islands must be viewed as extremely dynamic landmasses evolving progressively and becoming more, rather than less, complex. Man's influence in the natural history of island ecosystems must be viewed as negative, not positive. It can also be argued that in the context of its own ecosystem, and instability have increased since the arrival of man, though each island must be looked at on an individual basis in terms of stability. Energy on the human pressure on these island ecosystems has been reduced spatially, that is it has become spatially less pervasive and more intensive.

A caution concerning 'baselines'

Finally, while it is generally acknowledged that the swing from glacial to post-glacial, global climatic took place rather suddenly about 10,000 years B.P., it was not until about 5000 years ago that sea level rose to its approximate present position, and the present-day topography of the islands was established. The modern phase of environmental conditions, however, is still small-seeded islands therefore began very recently. It is also obvious that there was a time-lag between the stabilization of the environments and the establishment of a stable, internal, water, site, adjustments to this external control as well as to others. Thus, while the general, regional, external 'environmental baseline' was established about five millennia ago, individual island-environment 'baselines' must have been attained still more recently. Because the modern environmental conditions, however, have been much more constant since the last 5000 years, our instrumental and observational data base represents a mere one or two per cent of that period and is therefore dominated by short-term variability. Our analysis of this brief record has shown how very substantial spatial-temporal variability is present in these island systems. It is therefore not surprising that new, man-or naturalized, populations may be found locally for many people the islands have been inhabited by Polynesians and remain 'home in spite of hazards'. Temporal and spatial variability in physical inputs would thus appear to be more general in between individuals and species, however, the large number of small islands, the large number of species and the small size of the islands could possibly be attributed to the environmental fluctuations. Annual rhythms in fishery, cropping and other activities, for example, are useful responses to seasonal changes which ensure that particular environments are not over-exploited. Complete environmental stability, however, if it existed would probably be unsustainable because both man and his supporting ecosystems.

Special and temporal variability

The problem of establishing natural baselines for island ecosystems is put into perspective. In another section in this Technical Note Brookfield discusses the concept of 'extinction' historical, and recent human-use systems and environmental change and concludes that:

Except as a term which in a snap-shot, then, there is no real valid self-equilibrating system, old or new. The 'baseline' concept is a 'smoke screen' of quite rapid change in the size and structure of human systems. These concepts are not generally applicable to island ecosystems, natural and/or man-modified.

Island ecosystems and human use systems

These concepts are not generally applicable to island ecosystems, natural and/or man-modified.

A final analogy to one that emerges from Brookfield's analysis of dependency can be cited. Brookfield suggests that in the face of dependency there is local 'economic diversification' on small islands because of the high sensitivity to external variables. They are consistently being re-invented from outside and becoming internally more diversified as a result. So too with island ecosystems. We have already noted that they are constantly being subjected to fluctuations in environmental inputs and that one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified, rather than one result is that they are becoming more diversified.
nized consequences of external physical dependence on the one hand and economic dependence on the other.

Relevance for non-biosphere analysis

The foregoing illustrations suggest that there are methodological links between human use of space, natural events systems and island ecosystems. This is very relevant, for in studies of non-biosphere relations today there is an urgent need to integrate the social scientists' and natural scientists' approaches to the problems of small islands. All too often the enthusiasts for one approach regrettably exclude the other with which they are less familiar. What we now suggest is that there are a number of analogies between the concepts utilized by natural and social scientists and that those can serve as common ground for heightened understanding of the dynamic nature of island environments and economics. The utility of a combined input has to some extent been demonstrated in recent investigations of the Sahelian drought and the general problem of desertification. It is further illustrated in the present Technical Note on environmental and population of tropical islands.

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The Fiji study: testing the MAB approach

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1. PRECONCEPTIONS OF THE ISLAND PROJECT

INTRODUCTION

This section sets out to review the Fiji project in terms of its theoretical structure, and to indicate in what ways the ideas generated within and around the project may assist in the future evolution of MAB Project 7, and of the MAB Programme as a whole. In order to do this it is necessary to consider the empirical work of the project in the context of its own changing theoretical structure, and the latter in the context of the changing conception of the MAB Programme as a whole.

When this project first began the MAB Programme was still in its infancy; ideas carried over from the International Biological Programme had not yet been closely related to ideas generated from within the social sciences, and some of the critical stages in this fusion of ideas took place around the time when this project was itself being designed. A deliberate shift in emphasis made in the twelve months between the design of the first work plan and the actual commencement of field work was itself part of this change. The reporting stage of the project, which has already extended over a longer period than the field stage itself, has carried our work beyond the time of the 1977 meeting of the International Co-ordinating Council at which the central role of the social sciences in the Programme as a whole was emphatically reaffirmed (Unesco 1977).

The project’s ideas evolved in the context of these wider trends. Field work was carried out in a period when the social science role was still being established within MAB; reporting was done during a time when the main foci of the Programme were becoming more sharply defined. The work of reporting has, however, suggested the need for a new integrating paradigm, in which the relative roles of the social and natural science contributions might be clarified within a unified framework. The search for such a new paradigm is the purpose of this section.

The ideas presented here have therefore arisen largely from hindsight – notoriously a poor aid in the conduct of field research. However, this is a common experience, and apology is not necessary. In the section that follows, first place is given to the ideas that were current when the Fiji study began; then follows a discussion of what was learned in the field, and of the models that were sought – within the social sciences – as an aid in interpretation. Finally, it is suggested that these ideas might be developed so as to lead toward a new integrating framework, of service not only to MAB but to man-biosphere research as a whole.

THE ORIGINS OF MAB PROJECT 7

Project 7 differs from others in the MAB Programme in that it is concerned neither with a particular biome nor with a particular theme; it is concerned with a highly varied set of environments whose only unity is that they are small pieces of land entirely surrounded by water. The selection of islands as a special field for study of man-biosphere relations has been questioned on scientific grounds, and this questioning finds some support in the present analysis. In particular, reason is found to question the title of Project 7, which seems to assume the existence of some entity that can be described as an ‘island ecosystem’. But this term itself tells much about the original conception of the ecosystem and rational use of island ecosystems. Unesco, 1980. Population-environment relations on tropical islands: the case of eastern Fiji. (MAB Technical Notes 13).
The scientific significance of islands

Islands have for very long been thought of as a unique miniatures of larger, continental conditions. Yet the parameters can be readily defined, the behaviour of variables measured, and externalities either congruent or dissonant, in the recognition of the scientific value of islands as research situations in fact goes back to the time of Charles Darwin, and perhaps even further back to the 18th century. In an important book published in the same decade as Forbath's symposium, MacArthur and Wilson (1967, p. 3) observed that:

The study of island biogeography has contributed a major part of evolutionary theory and much of its clearest documentation. In the science of biogeography, the island is the first unit that the mind can pick out and begin to comprehend. By studying clusters of islands, biologists view a simpler microcosm of the seemingly infinite complex of continental and oceanic biogeochemistry. By their very multiplicity and their range of latitude, islands are a model of complexity, in the sense of isolation, and ecology, islands provide the necessary replications in natural laboratory models of evolutionary and ecological processes can be tested.

Islands do indeed have value as research laboratories for the most difficult and knotty problems such as population pressure on resources, resource-use conflicts, and the development difficulties of continental and oceanic islands, small parcels of resources and a skewed distribution of resources, can be ana lysed very effectively in an island situation, even though they are not unique to islands. But the laboratory value of islands is primarily biogeographic. It is therefore worthwhile to begin with this aspect, which is also of importance to the 'Islands of Science' programme of IUCN and to the biosphere reserve programme of MAB itself. To begin here will demonstrate how islands were first viewed in relation to the main issues of the MAB programme, and show how certain rather unrealistic expectations were generated -- expectations that have greatly to be modified in conclusion.

Islands as laboratories and as models

The statement of MacArthur and Wilson, quoted above, introduced a pioneer essay in the 'theory of island biogeography', empirical work has confirmed certain of the hypotheses advanced. In that work, especially those concerned colonisation and adaptation of species, the balance between immigration and extinction of species, and the related concept of 'carrying capacity' in so far as it applies to the non-human biota. It has, for example, been demonstrated that the post-glacial transitory, successional occupants of a niche in continental locations can become and remain healthy dominant microhabitats and, similarly in the absence of competition, biota can adapt themselves to changing environments over long periods of time, or colonise environments elsewhere dominated by other species. From this biogeographical point of view, whether or not the effect of human interference in incorporated, the peculiarities of adaptation of biota to environment in isolation would alone seem to justify the selection of islands as a particular research theme in the programme.

Models of wider complexity

There is, however, a further aspect of the scientific value of islands which is also contained in the quotation from MacArthur and Wilson, and which appears not infrequently in the literature of island biogeography. The island is a model of complexity, and the island has an increased degree of isolation, and ecology, islands provide the necessary replications in natural laboratory models of evolutionary and ecological processes can be tested.

Islands do indeed have value as research laboratories for the most difficult and knotty problems such as population pressure on resources, resource-use conflicts, and the development difficulties of continental and oceanic islands, small parcels of resources and a skewed distribution of resources, can be analysed very effectively in an island situation, even though they are not unique to islands. But the laboratory value of islands is primarily biogeographic. It is therefore worthwhile to begin with this aspect, which is also of importance to the 'Islands of Science' programme of IUCN and to the biosphere reserve programme of MAB itself. To begin here will demonstrate how islands were first viewed in relation to the main issues of the MAB programme, and show how certain rather unrealistic expectations were generated -- expectations that have greatly to be modified in conclusion.

The model study: testing the MAB approach


The island ecosystem project offers an exceptional opportunity. In theorising about human use of environments. The fact that much anthropological literature on small island societies is of a generalised and flexible species, for in most fundamental respects we hardly differ from other animals. We can participate in ecosystems, as do the populations of species; they occupy particular positions in food webs as do other species, but are regulated by factors little different from those that limit others. Man is sometimes able to devise and control habitats, but when he does he becomes bound by the demands of his own living invention. In the detail of man's commitment to, and participation in, the biotic communities in which he has been there is much to illuminate his socio-biological system. The study of man, the culture bearer, cannot be separated from the study of man, a species among other species.

Vulnerability of island environments

Rappaport's emphasis on adaptive non-environment systems justified their study for an island world. The island context provided the second justification. Islands are also very vulnerable to interference. As Forbath wrote (1963, p. 166):

It is clear enough that the arrival of man has invariably increased, to some extent, the degree of difference between his two systems. With the advent of modern man this increase has frequently assumed catastrophic proportions. The losses in organic diversity, soil development, water retention capacity, and biotic community organisation all amount to an increase in entropy and in cases of extreme degradation this increase has brought about a high entropy level. It is suggested that this is bad from any conceivable viewpoint.

Islands therefore model both man's destruction of his own habitat and also the conditions of steady-state adaptation to that habitat; by virtue of their small size, isolation, limited resource base and skewed resource distribution, together with their protection from outside competition - but extreme vulnerability comes into being if man is breached - they model these conditions for the whole ecosystem in extrem. The 1973 Expert Panel summed up the intended approach in these terms (IUCN 1973, p. 14):

A useful approach to the study of the rate of environmental changes is the concept of carrying capacity. The concept should include cultural, social and technological changes and their impacts on the various sectors of the island environment as well as the interaction of variables that are influenced by ecological and cultural constraints and opportunities. Thus, the capacity of the island ecosystem to satisfy changing human needs can be approached in a more integrated way than is usually feasible in other environments. It is hypothesized that most long-settled islands lie somewhere on a continuum between two extremes. At one end are those islands where external agents have had only a superficial impact on what were formerly closed, self-equilibrating systems (e.g. a few western Pacific islands), at the other there are those islands where the impact of the outside world is so profound that it has been hypothesized that, at least in the case of the study island, the culture bearer, cannot be separated from the study of man, a species among other species. 1

On Christmas island, south of Java, for example, Mangrove-aecial communities - a small, short-lived tree of the Malaysian rain forest succession is a long-lived canopy emergent. On the same island Eucalyptus gunnii, a eucalyptus of the Indo-Pacific region, has assumed a niche which achieves a height of 40 m uplift. Among bird life, the colonies of Aves's dovec (Dove abob) seem to have adapted their nesting habit to uplift over perhaps a million years. (Gillson 1976),
The social science input: human use systems

The ideas discussed in the previous section were not the only ones put forward in the Project 7 expert panel meeting. Six geographical and scientific representatives were among the participants, including representatives of international organisations invited to that meeting. Recognising the large existing body of work on islands carried out within the Natural Sciences, the panel emphasised the need for a balancing social science emphasis in any integrated programme for the study of islands. The state of development, and the degree to which island non-environment systems become 'open', as measured by the strength of their linkages with larger economies and their location within the spatial systems of these larger economies, were regarded as important variables in the classification of islands.

A tentative matrix was drawn up (Unesco 1974, p. 11), in which islands were classified according to whether they were 'developed islands', 'less developed islands', or 'undeveloped islands'. This classification, like all others in the matrix, is simply a starting point for the more detailed analysis of indicators of the problems of non-environmental interactions, which was to be the main topic of the meeting. The matrix was designed to allow for a more comprehensive analysis of the connections between the different systems of the island. The matrix was also intended to allow for a more comprehensive analysis of the connections between the different systems of the island.

The PIJ study: testing the MAB approach

A 1974 task force meeting on the role of the social sciences in the MAB Programme proved to be the occasion for crystallization of the search for a more viable conceptual framework. A major stumbling block was cleared out of the way by introduction of the concept of the human use system, defined as (Unesco 1974, p. 10):

organisms through which and by which resources are managed. They vary in size and composition from the household or tribal to the nation state or multinational corporation. In their spatial expression they are rarely, if ever, congruent with ecosystems. Indeed they are often expressed by introduction of the concept of the human use system, which is the subject of this section of the report.

Islands as isolates

Emphasis remained, however, on the study of islands as isolates, and there was more than a hint of 'preservation' rather than merely 'conservation' or 'management' in the 1973 discussions. A truly dynamic approach was most significant and it was noted, for example, that there was an absence of any real 'management' of the island ecology. The work of the project team was successful in opening up a new area of inquiry, but it was not yet recognised by anyone involved in the study concerned with man and the biosphere should therefore recognize that while ecosystems represent a sound scientific basis for investigating the environment, the ecosystems and the human use systems that rely on them are also of major importance from the prospective of human use of the biosphere, and in the context of the broader range of issues that go beyond the range of the natural sciences. It is clear that the human use systems are important in their own right, and that they are also affected by, and in turn affect, the natural ecosystems. The study of human use systems is therefore a necessary part of the broader study of the biosphere.
II. THE EVIDENCE FROM THE FIELD

When the decision to begin the MAI 7 pilot project in the Pacific, rather than in the Caribbean, was taken, the present writer had reservations. He feared that such a change would merely add to an already extensive literature on the progressive impact of external forces on well-structured Indigenous societies. However, it was found that in terms of human use systems and their controls those islands had far more in common with critical situations elsewhere than could have been supposed. Moreover, the unusual ecological variability of the islands made this inquiry particularly valuable as a case study.

Almost everyone of the project's initial hypotheses was reversed by the field study. When exposed to reality. The process of change was not linear. Evidence of heavy but violent impact on landscapes in the ancient past was uncovered, contrasting with the much more uniform impact of the modern period, weakening differentiation in resource use. While accentuating differentiation in society. It was established that loss of internal capacity to manage environmental and other variables was perhaps even greater than in more populous islands elsewhere in the world, exposed to massive external impact for a longer period of time. The effect was to reverse the 'less developed' to 'more developed' continuum that the 1973 expert panel meeting had postulated. It was possible to reject the notion that these islands, as man-environment systems, are microcosms of conditions in the world as a whole. They are, however, best represented by those large parts of the

earth that have been rendered 'periphery' by the spatial structuring forces of world development.

MAP AND ENVIRONMENT THROUGH TIME

The 'baseline' and before

It will be useful to concentrate on only a few of the project's findings in elaborating the statements of the paragraph above. The first set of findings concerns the interaction of historical change and environmental conditions. It is necessary first to restate what was already well known, though it has been possible to add a few details.

The baseline for study had been determined by the accumulated knowledge about the condition of those islands in the 18th and 19th centuries, established by the work of Thompson (1938; 1940a; 1946; 1969; 1970), Hocart (1925; 1952), Sahlins (1962) and others. In the 18th and 19th centuries these ecologically varied islands were managed under a range of agricultural techniques specific to different crops and to different site conditions. Several distinct forms of irrigation/drainage technology were in use for the cultivation of crops, with only Lithosols in patches among limestone karst, labour-intensive mulching systems were employed, mainly to grow pith of the islands was cultivated, with the aid of deep-tilling of the soil. Elsewhere, less-intensive technologies were used.

A well-elaborated system of inter-island trade and interdependence made possible the continual exchange of goods. Geographically variable different islands and parts of islands in a human use system that extended throughout the region managed to share resources on the limestone islands were employed for the manufacture not only of wooden articles of considerable variety but for construction of the largest and most seaworthy of all craft built in the western Pacific in this area. It was these latter craft that enabled adventurists and later colonists from Tonga, and made possible the creation of sea-states in eastern Fiji that dominated the whole Fijian region until the 1870s.

Characterisation of the pre-colonial system

This system, which was destroyed by colonisation, had a number of interesting structural characteristics. First, it seems to have supported a distribution of population not greatly different from that of the pre-

day - that is, a distribution greatly different from the settlement carried capacity of an archipelago that includes as extraneous recent volcanic islands of very high fertility and limestone islands almost devoid of what modern cultivation would class as 'arable' land. Second, although the pan-island power centres were on islands having advantages in terms of size and resource diversity over their immediate neighbours, the size and spatial variability of the resource complexes of the adjacent mainland coast came to be dominated from the small islands, rather than vice versa. The system of power was based on control of the sea, and hence on marine technology and military skills more than natural resources. Third, though the system certainly contained some elements of high antiquity, its structure as encountered by the first literate visitors was a creation only of the 18th century, and its final elaboration was an indirect consequence of early colonisation itself.

Changes over a longer time-period

The islands in a much longer prehistory, about which only limited evidence is available. For Taveuni, Frost (1969) established the presence of settlements about 250 B.C. with the introduction of massive fortification about 1000-1200 A.D. For Labasa, there is strong evidence of occupation before 1500 B.C., according to evidence from elsewhere in this part of the Pacific, but this project has found evidence to suggest a major landscape transformation only sometime in the period between 0 and 500 A.D. - evidence that is still being analyzed at the time of writing. Much of this early and mainly non-Britonic island is now covered by a barren fern-carribean fire-complex known as 'talepa', developed mainly on Feralic Gambols that are widely truncated by erosion. The project set out to test the general belief that this is a 'man-made desert' resulting in disastrous loss. Recent clearance of forest, using fire and初始/slaughter/cultivation of the land. The evidence of these findings makes clear, together with the presence of the 'talepa' soil-vegetation complex, this evidence is suggestive of early landscape transformation on the island.

Implications

From the point of view of regional prehistory, these findings mesh with the discovery of skilled water-control agriculture
In central New Guinea dated as long ago as 7000 B.C., and new evidence suggesting possible human interference for agriculture in southeast and southwest New Guinea (Culkin 1977; P.B. Hughes, personal communication). From the point of view of the basic assumptions that underlie the indigenous people in this area, they had the major shift in the early part of the 6th century that swept down the length of the Louna chain in January 1975, coinciding with a steep decline in the new vegetable-growing economy. The collapse of the tourist market for the handicrafts to which the Louna craft workers had turned, no self-sufficiency in the vegetable-growing economy, and the whole region became heavily dependent on the bounty of central government, aided by some overseas disaster relief. The project made a special study of the bushcane operation and its impact in Lom in 1975 (McLean 1977; Bayliss-Smith 1977; K. Brookfield 1977; Campbell 1977) and concluded that what had occurred was a 'crisis of dependency' far more than just the impact of a major, but not necessarily devas- tating, storm. Furthermore, this study emphasized that the most serious loss was the income on which islanders had come to depend for about a third of their needs; the relief system did little or nothing to replace this loss, and all that it meant in terms of deterioration in the quality of life. There were also opposing trends. Already by the 1920s there were some indications of the reestablishment of resource-use patterns, through early initiatives in the cultivation of cash crops for the urban market and the planting of crops for personal use. By 1950 and especially since 1970 this new avenue of development has been greatly influenced by the spread of new forms of rice cultivation. It is clear that the current balance between the cultivation of new crops and the increased vegetable-growing economy has been greatly influenced by the shift away from the cultivation of new crops and the increased vegetable-growing economy. In the present period the balance of the migration has generally been outward from the eastern provinces, although in recent years, the movement has been greatly influenced by the shift away from the cultivation of new crops and the increased vegetable-growing economy. These changes in natural trends due to the ongoing movement of people, the increased cash crop cultivation, and family planning programme and fertility decline, are other major changes in the present period. The implications of migration Migration has been of major importance in every region, but where detailed research has been undertaken. In Rabaul, Papua New Guinea, the writer once spent several profitable weeks of fieldwork collecting information about the migration of the islander population from the Solomons and the migration traditions of the islanders. They appeared to have been occupied in the past century with the migration of islanders out of the mountains into the larger adjacent valleys and the displacement of other people further afield (Brook- field and Jrom 1963). To this random example may be added another, that of the Chirujo (1958, p. 32–3) records that on remote and isolated Tikopia, east of the Solomons Island tradition has it that the islanders displace themselves from stocks originating in Tonga, Samoa, Rotuma, and Niuatoputapu, the Banabas group in the northern New Hebrides, and the Solomons group in the Solomons. In interpreting their computer simulation of 'chance' voyages in the Pacific, Lewis, Hard and Webb (1973) assembled a considerable body of data concerning the ancient movements of Pacific peoples. They have shown that the whole region came to be inhabited long before the colonial period. It is only in a small number of cases that the Polynesians, the Melanesians, and the Micronesians have been found to have settled in the eastern Pacific. The implications of the Polynesian, the Melanesian, and the Micronesians have been found to have settled in the eastern Pacific. The implications of the web, and the great unoccupied areas of the world. The implications of the web, and the great unoccupied areas of the world. The implications of the web, and the great unoccupied areas of the world. The implications of the web, and the great unoccupied areas of the world. The implications of the web, and the great unoccupied areas of the world.
set up the dominant chiefly mataqali, and establish the large settlements in each place. In modern times, the land poor and disposessed have been the more mobile, first because of the larger land holdings, and later to Suva which, since 1960, has drawn migrants from all islands, all races and all classes. Although resem-
nersing the 'theory of island biogeography' has been traditionally applied to humans in these islands, notably the Fijian practice of driving 'excess' groups out to see to perish. This view of a 'crying capacity' is bedevilled by this movement, for people may migrate in search of power, wealth or opportunity — reasons that bear little relation to the biological capacity of individual islands to support the real or perceived needs of their occupiers.

INEQUALITY WITHIN HUMAN USE SYSTEMS

The third main group of findings which is introduced here was not foreseen in any way in pre-field planning. It was known that Fijian society is structured by rank, but this was supposed to be sustained by a redistributive system, alliass to the recip-

In this 20th case the individual and groupings at large Fijian literature would confirm that this is so. It was also known that the land poor, but the project supposed, along with other writers who had looked at the larger Fijian society, that it had compensated for this by assurance of better opportunities consequent on the level of the dominant European companies and individuals, and the Fijian peas-

Within Fijian society, the project sought in terms of groups, down to the lowest levels of the hierarchy, nested within a series from nation, through region, island, village, clan (mataqali), subclan (pato) and household, such as Sahlins (1962) and other writers describe. The writer and his col-

On the other hand, the landlessness of the British colonial system, with its exaggerated development of a class of landless alienated, was especially important because of the obligations of the chiefs, on the other hand, were freed of their enforcement on the people, with much of the land already taken up for other purposes. Unemployment was not found to be in the present or historical past in this region. Whatever change was there before the record begins, it was a period of social disintegration, more on some islands than others. In order to find models for the interpretation of these islands as man-environment systems it is necessary to look beyond the original notions, and seek ideas from the more dynamic theories of development and underdevelopment. Specific studies of the society and its economy, such as the Fijian economy, have been pursued, but the many islands and mainland are very strong, especially as more than half the rural population of some islands now lives elsewhere.

The Fiji study testing the MIB approach

is already creating yet another new class of landless families among the present genera-
tion. The result is an unequal distribution of rural incomes that is probably growing more unequal at the present generation. All this has arisen on some islands in the presence of abundant and under-utilised resources.

Implications

Even the notion of human use systems was modified by this finding. Basically, the notion assumes that the 'system' operates for the benefit of its participants as a whole; it does not allow for gross inequalities within such systems. It is no longer possible to treat whole islands, or their constituent village and mataqali territories as collective human use systems without qualification; it is necessary instead to build 'human use' constructs upward from the household level, and determine how far traditional grouping still structures behaviour, rather than social class. In its field investiga-
tions the project was too bound by its initial ideas to make adequate adjustments to these discoveries; it is only in subsequent analysis and reflection that it is possible, to some degree, to correct the original bias.

CONCLUSION

At the time of writing, the detailed reporting work of the project is only just com-
menced. The project is to report on the human use systems of the small islands of Fiji and make them available for comparison with the small islands in the historical past. The report on human use systems is not to be found in the present or historical past in this region. Whatever change was there before the record begins, it was a period of social disintegration, more on some islands than others. In order to find models for the interpretation of these islands as man-environment systems it is necessary to look beyond the original notions, and seek ideas from the more dynamic theories of development and underdevelopment. Specific studies of the society and its economy, such as the Fijian economy, have been pursued, but the many islands and mainland are very strong, especially as more than half the rural population of some islands now lives elsewhere.

in all these there is little to distinguish the long islands from many other parts of Fiji, and many inland parts of larger coun-
tries. As a whole then, the project did not find that 'the capacity of the island ecosystem to satisfy changing human needs can be approached in a more integrated way than is usually feasible in other environments'. This is not to deny that islands, being vis-
ably bounded by salt water and only inter-

cently linked to other land areas by use of sea and air transport, do not maintain a very large measure of distinctiveness, es-

pecially in the perception of their own people. For the same reason islands have advantages as units of study, but as bounded areas linked to larger entities, and not as isolates.

Above all, it is necessary firmly to re-
ject any notion that these islands in the western Pacific can provide a 'baseline' against which change in 'more heavily impac-
ted islands' could be evaluated. Instead there is evidence of change going back through perhaps 2000 years, and of major reconstituta-
tion, and constant change in the human use sys-
teme and their management of environment during historical time. These islands are as 'heavily impacted', as others.

However, these islands are representative of peripheral regions within third world countries, and are interrelated with-
in the international system. Although be-
ecause of emigration there is not such a clear perception of this area is very considerable inequality. Not all the supposed hierarchical structures has passed, but there has been a very con-
nected and increasing rate of social disintegration, more on some islands than others. In order to find models for the interpretation of these islands as man-environment systems it is necessary to look beyond the original notions, and seek ideas from the more dynamic theories of development and underdevelopment. Specific studies of the society and its economy, such as the Fijian economy, have been pursued, but the many islands and mainland are very strong, especially as more than half the rural population of some islands now lives elsewhere.
DEPENDENCY THEORY IN SMALL COUNTRIES AND ISLANDS

Characteristics of island countries

Some recent papers by UNCTAD (1977) apart, that segment of the development literature which concerns islands is only a part of a larger interest in the small island countries. However, most of the argument at small-nation level is quite surprisingly applicable to small-island units within nations. The literature about small nations and their problems has grown in volume as the number of very small nations has increased. The significant start is with Robinson (1960), but the decisive step forward was the work of Dumas (1965), itself the crystallization of a decade of Caribbean economic thinking. A useful collection of essays written from outside (Benedict 1967) was the first to focus on non-economic peculiarities of small countries. In the present decade, Selwyn (1975) has drawn together a wide range of experience and ideas on the problems of being small and isolated in a developing world. Most recently, Selwyn (1978) has revised and expanded his own contribution to a 1975 UNCTAD study in a manner that is very relevant to our present problem.

The problems of small size

Small countries are a special class within the world comity. It has often, and correctly, been observed that most of the world's problems are rooted in the fact that all small countries also include some of the world's richest, and small countries are in fact a very heterogeneous group. Although the range on a per-capita GDP basis, the fact of smallness is not itself any significant indicator of the state of economic health. Much more reliable among the correlates of smallness is an almost universally heavy reliance on foreign trade; in a great many island countries, imports by value are equal to or greater than half the GDP, and in some cases larger than the GDP (Selwyn 1978, p. 9).

Even more general, a correlate of smallness is that elusive 'quality' of dependency, defined by Dumas (1965) in terms of external control of the key sectors of the economy, reliance on foreign aid, human resources and expertise, and on imported consumption and production patterns which are the underlying causes of the dependence on trade. Very few countries are metroplis; almost all are

'hinterland' in Griven's (1970) sense of being 'takers' of economic organization, capital, technology and information, and having no share in the exportation of these factors. This very negative view requires some modification in PF, and perhaps even in the West Indies themselves, but it has service. Selwyn (1978) also calls attention to the very common weakness of many small nations, 'leading to a serious dependence on food imports. He also remarks on the lack of association in small economies between those indicators variables which, in larger and more independent national economies, tend to move in harmony. He goes on (1978, p. 11):

Thus dependence is not merely a question of the relation between the island country and the rest of the world; the country's own economic and institutional structure will reflect its external dependence. This is a statement with ecological implications.

Dependence theory

While the search for a successful economics of development in the universities and institutions of the West remains for some twenty years concerned primarily with the macroeconomic and interdependent national system, a very different sort of analysis was evolving in some parts of the developing world. At first, this was concerned with rejection of primary-product export as a basic for growth and with the need for industrialization. Later, and with greater force as the industrialization model failed to deliver the expected results, schools of thought emerged that were concerned with the historical and structural analysis of the causes of underdevelopment and its institutions. This 'dependency theory' arose almost independently in Latin America and in the Caribbean, having a rather longer and deeper history in the former than the latter. Griven (1973) traces this parallel evolution of a new paradigm that, since 1970, has won growing acceptance in a much wider world.

The most important characteristic of the dependency school has been its emphasis on historical analysis; whereas the study of 'development' was a part of economic history before the Second World War, it thereafter ceased to belong to this area in the West, and only after a generation-long gap has the need for empirical historical relevance of assumptions again impressed itself on any large body of Western economists. It was not so in Latin America and the Caribbean, where the origins of continuing national and regional underdevelopment are thought in the colonial past, in the impact of the European and American industrial revolutions on their economies, in the process of colonial trade and in the 'new mercantilism' of the multi-national corporations. The concrete patterns of national institutions both on a world scale and within countries was born and was largely elaborated in the Latin American context; the historical processes interpreted and postulated could therefore also be seen as the processes by which the spatial patterns of underdevelopment were generated.

The theoretical strands involved are many and complex, but the emphasis is on the interdependency of all the related phenomena. The central conception is of a global system of development and underdevelopment creating polarization both between and within countries. Models based on 'closed' national economies - as are those of much of growth economics - are rejected because no economy is closed. Income distribution becomes important because inequality in a dependent sub-system in the global whole tends to aspire to the consumption patterns of the dominant national sub-systems; since they are also the decision-makers at the national or regional level, their distribution also become copes of those taken by the 'decision-makers' in the global system. Hence great, and possibly excessive emphasis will be placed on the roles of the multinational in the structure of dependency. Other forces generating 'imitative' goals for development lead, however, in the same direction.

Exploitation theory

Integration and national and national integration

In a paper first written in 1970, Oswaldo Sunkel (1973) introduced a further argument of importance. Sections of the population of a dependent country become tied in various ways to consumption patterns and also privileges made possible by their relationship to a dominant country or multi-national corporation. This applies not only to the bourgeoisie, but also to a relatively well-paid 'labour aristocracy' and to other client groups. The concept of transnational integration is therefore also one of national integration. The Caribbean dependency theorists take a parallel line. The West Indies Federation, they argue, was forsedaken, because the English plantocracy and London group within islands, had its own trading, financial and cultural links with the metropoles, and very few real geographical barriers. In the post-independence situation, the West Indies 'middle class' has interests quite different from those of the white establishments, and while within the working class, privileged sectors associated with dominant activities such as sugar and rum, had the advantage to defend their advantages against their own fellow. Extending Sunkel's argument in a wider context, we could therefore hypothesise that the greater the degree of integration of a dependent region into organizational structures based on a dominant centre, the greater will be the disintegration of locally-based structures within the dependent region.

Some more dependent than others

A means of testing the hypothesis advanced in the preceding paragraph can most readily be found in Selwyn's (1978) assertion that the internal economic and institutional structures of dependent countries - or regions, or islands - will reflect their external dependency. The structure required will then bear both on economic dependence and also on the want of effective decision-making over economic resources free from external pressures. A heavy dependence on exports and imports, especially where both are handled through a few large trading houses and companies; weak governmental and administrative structures, with areas that are effectively controlled by non-local; dependence on the exterior for information, education and innovation of all kinds - these would then be the main both of dependence and of 'local disintegration'.

It is very generally thought that small countries are especially vulnerable to forces beyond their control because of the small size and skewed distribution of their resource base. A national economy whose 'modern sector' is dominated by only one or two mainly foreign-owned industries, be these mining, plantation agriculture, tourism or whatever, will find that they have little scope for economic decision-making. West Indian theo-

1 For an expansion of this abbreviated discussion, the reader is referred to Brookfield (1970, p. 126-65), and, along a wide range of literature, to Furtado (1970) and Beckford (1972) for a more detailed presentation related to particular conditions. A further Marxist approach is presented by Cockcroft, Frank and Johnson (1972), among many other sources.
Diversity within dependency

The case of the New Hebrides is worthy of note in this context (Brookfield 1975, p. 56-72), and in particular informative because of its parallels with Fiji away from the core region. At the national level, we would seem to have a classic case of dependency. Land alienation is heavy. There is only a single export crop of importance, produced both by estates and peasants, and marketed through foreign companies. 'Economic diversification' has taken the form of mining, timber-getting and deep-sea fishing controlled and operated by foreign companies which produced a sudden rush of new foreign bank-controlled companies into the New Hebridean development'. Overseas links depend entirely on foreign carriers. Yet the economy of the New Hebridean peasantry, and even of some estates, is much less 'dependent' than might be suggested by the structure of the national economy. Indeed, we might argue that the owners of smallholdings and small islands have their own 'diversification' in the form of subsistence, production for the local market, and exploitation of local business opportunities. Currently, New Hebridean producers have resisted intrusion in their political structures and are approaching self-sufficiency with a strong sense of nationalism.

The degree to which society has been able to retain control over its development varies. Allocation decisions taken at the local community and household levels is a variable almost totally neglected in the literature available. In the West Indian thinkers tend to ignore this variable in their own society, being - in the view of at least some observers - too much obsessed with their history as slave-based economies; Latin American writers are perhaps too obsessed with the heretofore and the institution of penance. Sunkel-type disintegration has not penetrated to the roots of society in any meaningful way. This is quite another matter of rural society. The 'basar' or informal sector of the urban population preserves something of the same independence in decision-making in most Asian and Pacific cities, with important political as well as socio-economic consequences (Armstrong and McCall 1973; Nolte and Young 1977).

Islands at geographical disadvantage

It does not appear desirable to examine, in this context, Selwyn's (1978) notion of 'disadvantageous geographical location' in relation to the condition of small island countries. Much of the literature assumes peripheral location in regard to the economic activities of a county or region to be totally disadvantageous. In terms of the 'modern sector' this is certainly real, as our studies in Fiji demonstrated in this case. In the West Indies there is a very great contrast between the 'more developed' and 'less developed' countries of the region, in the terminology of all literature since the 1960s. Barbados, for example, with its sugar estates, port, strong industrial sector and large tourist industry is far 'wealthier' than St Vincent. The latter has tourism only as an enclave industry on the offing Grenada; manufacturing is minimal; export agriculture dominates; coffee, bananas and arrowroot, but there is also a regional export of foodstuffs, much of the trade handled 'on shore', to Trinidad and Barbados (Brookfield 1978a). If now industries are attracted to such areas as the southern islands and the eastern Caribbean, they are more likely to go to the 'core' on St Vincent in Fiji, Trinidad and Barbados, than to 'peripheral' areas such as Tuvalu, Tonga, and the eastern islands of Fiji, St Vincent and the other Windward Islands (Selwyn, 1978). All this is true. However, 'geographical disadvantage' can also contain some compensatory advantages. Local society in the New Hebrides was not overwhelmed and it was in part of New Caladonia because the impact of the 'integrated/disintegrative' forces was, therefore, less severe. One of the consequences of the 1930s, and never revived (Brookfield 1972, p. 69-71). The New Hebrides are 'periphery' within the regional economic space, though in the world, it is worthy of remark that Swaziland, Lesotho and Botswana would hardly have survived to today if they had not been linked to the international exchange, nor for their 'geographically disadvantageous location' in the spatial structure of the south African economy. It is this only a matter of rural society. The 'basar' or informal sector of the urban population preserves something of the same independence in the demands for 'regional policies' involving devolution of power in some western Pacific countries, the separatist movement in Bougainville and the local secession of Tuvalu from the Gilbert Islands. Strong feelings of local particularism have also penetrated to some rural groups off northwest Europe, and this survival independence of mind has recently surfaced in the Shetland Islands, where we know the Ango-Scoottish quarrel concerning not only 'devolution', but more significantly the economic profits expected to flow from North Sea oil.

APPLICATION TO FIJI

Taken as a whole country, Fiji is peripheral to the world economy and has many of the structural characteristics of dependence identified by the Caribbean writers. In the same context, however, Fiji as a whole would be a 'more developed' country within the South Pacific, and even more clearly a 'core country' having functions as an entrepot, a provider of manufactures, especially services and perhaps even ideas to the 'less developed' or 'more peripheral' surrounding countries. Among the group of five island countries within the South Pacific Forum, and excluding Papua New Guinea, Fiji accounts for over 90 per cent of intra-regional exports (Selwyn 1978); some ten per cent of Fiji's manufactures are exported, overwhelmingly within the South Pacific region.

But Fiji is not one island. The 'core region' of Fiji is the Suva city area together with the 'growth area' around Nadi International Airport and nearby Lautoka. Much of the rest of the country, including even Vava'u Levu, is peripheral to this core in a more complete sense than are Tonga and Tuvalu, which have separate governments. Fiji's eastern islands are dependent periphery in every possible sense. Their former political independence, which persisted into the threshold of the 'integrated/disintegrative' forces, was replaced by a single export crop of importance and most of the better land in the region is devoted to its production. The trade goods are imported; all fuel, even most of that used in cooking, and all made-up clothing and the cloth for local foodstuffs are imported from outside, through Suva. Plantations and Government are the only significant employers of labour. Only some of the plantations remain in Fiji-resident hands, and among the three government stations in the eastern islands none has a full suite of departments; one does not even have an elected District Administration. With only minor exceptions all shipping is provided from Suva. Inter-island traffic on Fiji's little part associated with minor core-periphery subsystems around Levuka and the un-named 'town' in central-west Efate has declined almost to vanishing point. Even intra-island trading, formal or informal, is only very weakly developed. Owing to the distances posted to these islands it find it very difficult and costly to acquire local supplies.

Resistance to disintegrative forces

The close correlation between local disintegration and wider integration postulated above on the basis of Selwyn's arguments, seems to be borne out very clearly, and can be traced to a greater or lesser degree over the whole region. Parasitically, but interestingly it is perhaps most marked in the most developed of the islands (Taveuni) which, even though it has its own local centre-periphery subsystem, also has the most significant influence over the want of local integration and even communication between its different human use systems. None the less, there has everywhere remained a very considerable measure of local autonomy in the matter of decision-making over produc-

1 The 1973 Export Panal (Unesco 1973, p. 65) called attention to the special problems of these islands. Some numbers of the panel felt that this scattered group of island communities presents problems as interesting and significant in the wider study of islands in the modern world as any in lower latitudes. Indeed around 1900, the whole structure of society in the Shetland Islands still seems to have been preserved, and the only economic exports - fisheries, sheep and birdlime - were directly dependent on Suva, and all links with the larger world economy mediated through the port. Though the single export crop of importance and most of the better land in the region is devoted to its production.

1 It is not easy to explain customs as much more gentle, courteous, and persuasive than those of the ordinary British family of all classes. Before, one cannot but admire the skill of their feudalism had been unaffected by industrialization and urbanization. Less than that which we have found in our own society.

1 For a more complete explanation of the concept of 'feudalism' see Young (1975, p. 28-31).
Economic policies.

Although the economy of Nacasmak is geared to the sea, there is a strong tradition of subsistence farming. The islanders are known for their hard work and creativity, and their ability to adapt to changing circumstances. The government has encouraged the development of local industries, such as coconut oil production, and has provided financial assistance to small businesses. However, the islanders have also developed a strong sense of community, which is reflected in their cooperative efforts to address local problems. The government has also worked to improve education and health care, and to provide opportunities for women's empowerment. In addition, the islanders have a strong tradition of cultural expression, and have been recognized for their unique music and dance. Overall, the islanders have a strong sense of identity and pride in their cultural heritage. However, they also face significant challenges, such as climate change, which has affected their traditional way of life. The government has been working with the islanders to develop sustainable practices that can help protect their environment and ensure their long-term well-being. The islanders have also been actively involved in these efforts, which has helped to strengthen their sense of community and pride in their culture. Overall, the islanders have demonstrated a strong capacity for resilience and adaptability, which is an important asset in the face of ongoing challenges.
To pursue this argument further would be beyond the scope of the present paper; it will be developed in another place. For the present, however, there are some quite important implications in terms of the interpretation of human use systems, what we seem to be dealing with is not a comprehensive hierarchical systems,...

IV. HAN-BIOOSPHERE SYSTEMS AS STRUCTURES IN TRANSFORMATION

The argument in a different context

The purpose of this final section is to attempt a synthesis, and in so doing to propose a further shift in the theoretical evolution of the MAB project. The argument departs substantially from the context of the island project in the process. The Fijian study was carried out on the full swing of the pendulum toward a greater emphasis on the contribution of the social sciences to the programme; this final report is itself an attempt to bring about greater integration. But it is not my intention merely to formalize the argument concerning human use systems, and second to seek means of relating processes within human use systems conceptually to natural processes occurring within the biosphere. Before undertaking either of these tasks, it may be helpful first to recapitulate the argument up to this point, but in a wider context than that of the MAB Programme.

Before the 1960s human-environment theory was still dominated by a reaction to the environmental issues of a much earlier generation. Those sciences principally concerned with man’s activity within and in relation to his natural environment—geography and anthropology—had each turned to a strong emphasis on inductive method in which environment was seen as a set of possibilities and constraints, and emphasis was placed on the actual phenomena of human activity as seen, described and interpreted (Crossman 1977). These approaches, generating a concern with spatial analysis in geography and with social structures in anthropology, led toward the solid body of grounded theory which has been swiftly taken up within MAB under the banner of the human use system. Meanwhile, introduction of the man-in-the-environment system during the 1960s offered an opportunity to conceptualize concepts, but they were trapped in the search for equilibrium-seeking forces, homeostatic and adaptive behaviour, which was still within the context of the contemporary analysis of natural ecosystems. Efforts to apply the man-in-the-ecosystem concept were effective in so far as man’s activities were viewed as an input into natural ecosystems (Unesco 1972), and from the social sciences side some successful studies were undertaken in small, virtually autonomous societies of low technological development. These approaches were, however, ineffective in the interpretation of rapid and secular change. A concept that could be viewed as invaluable at both the global scale and at the scale of micro-analysis proved to be incapable of application at intermediate levels. While it is clear that dependency theory provides a system of analysis within which most of the processes at work in ecosystems are viewed, marginalized groups within developing countries can be analyzed. It could be added that the argument is still in the process of development because animated by the development of ideas advanced in the 1975 meeting on the role of the social sciences in the process of development. While the concept of the human use system was first fully advanced at this meeting, and its relation to other processes was defined in terms of management and exploitation in a manner that has proved to be highly rewarding, the same meeting also witnessed emphasis on the contrasted nature and rate of operation of human and natural processes. Since 1974 there has been a vastly increased emphasis on the effects of human activity on the operation of natural processes, at all scales from the global climatic variation to the effects of water milles in the arid zones and depositional processes of small streams, to cite only two examples. These developments have come almost entirely from the side of the physical sciences, within which new fields such as environmental geology, geomorphology, ecology, climatology, hydrology, medicine, engineering, and the like have begun to emerge as integrated disciplines with their own structure, theories and rapidly growing literature.

Though it began much earlier, most of this development has become strongly visible only since 1974. The relevant social sciences have been able to use rather effectively in an increasingly bitter debate between a new and more radical left and an older liberalism, to the virtual neglect of the now marginalist position of a very recent earlier generation which was not primarily concerned with social welfare. As a result, the social scientist who is concerned with man’s impact on his environment now finds more rewarding reading in the physical sciences journals than in his own periodicals. Yet, paradoxically, it is to the conflict within the social sciences that he must still turn in search of theoretical insights with which to resolve the reformulated man-environment question which all these developments have given rise to.

Opposition within human use systems

The first question to be resolved, therefore, concerns the processes at work within human use systems. Only when we have succeeded in formalizing this argument can we proceed to the larger question which lies beyond the local level. But it is clear that dependency theory provides a system of analysis within which most of the processes at work in ecosystems are viewed, and that a new state of affairs has been created in the process of development. While the concept of the human use system was first fully advanced at this meeting, and its relation to other processes was defined in terms of management and exploitation in a manner that has proved to be highly rewarding, the same meeting also witnessed emphasis on the contrasted nature and rate of operation of human and natural processes. Since 1974 there has been a vastly increased emphasis on the effects of human activity on the operation of natural processes, at all scales from the global climatic variation to the effects of water milles in the arid zones and depositional processes of small streams, to cite only two examples. These developments have come almost entirely from the side of the physical sciences, within which new fields such as environmental geology, geomorphology, ecology, climatology, hydrology, medicine, engineering, and the like have begun to emerge as integrated disciplines with their own structure, theories and rapidly growing literature.

Though it began much earlier, most of this development has become strongly visible only since 1974. The relevant social sciences have been able to use rather effectively in an increasingly bitter debate between a new and more radical left and an older liberalism, to the virtual neglect of the now marginalist position of a very recent earlier generation which was not primarily concerned with social welfare. As a result, the social scientist who is concerned with man’s impact on his environment now finds more rewarding reading in the physical sciences journals than in his own periodicals. Yet, paradoxically, it is to the conflict within the social sciences that he must still turn in search of theoretical insights with which to resolve the reformulated man-environment question which all these developments have given rise to.

Opposition arises at every level. In varying degrees, nation states are opposed to multinational forces of integration/integration; provinces or regions may oppose collective action by a central government; island and village communities may resist the dictates of the centre, but may also seek to retain their freedom of decision and action rather than surrender these in favour of the 'monomodal'. Since this argument arose on the basis of Fijian evidence it is important to stress its generality. In eastern Fiji the project recognized emergent forms of class structure which were partly new, and which in part accentuated the ancient distinction between chiefs and commons. Much of the local opposition to the centre was structured on traditional lines. But such entities are not to be thought of merely as "survivals" of pre-modern structures into the contemporary system. On the contrary, it is argued that such local human use systems as the village or mataqali would no longer exist as active entities were they not able to operate effectively in the modern context. Nor in any case are they wholly 'traditional'. Many villages are neo-local groups, being associations of descent not rooted in the so-called developed country, but this is not the place in which to elaborate this conception. Within dependency theory, Hunkel's notion of national disintegration as a corollary of international integration has been shown to be particularly applicable. Alarmed, this notion says precisely what the 1974 Unesco task force was seeking to demonstrate in a number of the developing systems are absorbed by, and transformed by, larger systems in the process of development. Local decision-making structures are reduced to client status within larger decision-making structures; division of labour, and division of resources use, are reallocated in terms of the demands of the larger absorbing system or hierarchy of systems; in un-Fijian terms the interdependence of a small and varied archipelago is destroyed and replaced by dependence on the centre and the world system which lies beyond it, with the consequence that the mere flux of resource allocation was overrun by monoculture and the imperative of a scientific approach to totality. However this is not all. Opposition arises...
protective legislation and the active intervention of the state in defence of its members were the inevitable and 'unplanned' consequences.

Except in adders,,line and ferret, Polamyi did not extend his analysis into the transformation of countries subjected to colonialism, nor did he emphasize, as capital operated with even fewer constraints than in its homelands. Yet the dramatic changes that have occurred through continual and often painful adaptation, successful transformation was often achieved.

A Digression on Arista

Notwithstanding the emphasis given in the argument to the opposition of forces and to adaptive behaviour in the face of external pressures, it may reasonably be assumed that long continuance of essentially unchanged external and internal conditions would yield the equilibrizing behaviour that writers in the cultural ecology school have described and modelled. However, the existence of such equilibrium, even in isolated, autonomous societies, can be only assumed in the absence of diachronic data over a long period. Recognizing this, some cultural ecologists have focused on the forces operating under somewhat different conditions in order to propose a set of transformation rules in response to change (e.g. Baylis-Smith 1977b, Noren 1977). In drawing up such scenarios of cultural evolution, however, it is necessary to take into account the complexity of the crisis, and a brief digression on this topic will both assist conclusion of this argument and lead back to the theme of the interrelation of human and natural processes.

At the global scale most crises have arisen with the outbreak of war, and the effects of major climatic change cannot be isolated with certainty. At the local level, however, an example of crisis is rarely internal but far more commonly some change in external conditions, natural or human, and crisis may arise also from short-term events which involve no long-term change in the external forces. The crisis may only be temporary, but its nature can be revealing in clarifying underlying weaknesses in structure. For example, Sahlin (1972, p. 128-30; 143-44) calls attention to the consequences of severe hurricane damage on Tikopia in 1952 and 1953, as described by Firth (1959). In a famine period after the second hurricane the kinship-structured system of property and distribution began to disintegrate. The authority of the head of the lineage was discredited and their land and crops were violated. Sahlin emphasizes Firth's comment that the effect of famine was to 'reveal the solidarity of the elementary family'. Not dissimilarly, Baylis-Smith (1974a) and M. Brookfield (1979) both remark on the divergent behaviour of individuals and families in response to stress when a localized phenomenon simultaneously smote the Fijian island ofOVabuya.

In both these cases the crisis may have precipitated secular change. Tikopians began to emigrate to other parts of the Solomons Islands; in Lakeba some land-use changes may have been accelerated, but whether or not such changes followed, the local systems were demonstrated to have failed, as collectives, to strengthen the individual against external forces. Crises of a more serious order rarely leave adaptive structures intact. The Irish potato famine of the 1840s, for example, brought to an end a whole period of Irish history and initiated another (Woodham-Smith 1962). In the latter case the precipitating cause was no more than a series of humid seasome facilitating spread of a potato blight which wrecked a monocultural subsistence economy, but the underlying cause lay in the structure of the society and in the major transformations of the western world which rendered the condition of the Irish economy unworkable. The complete destruction of the old Scottish highland economy in the same period was brought about mainly by the choice of the peasantry to make way for sheep; the potato famine of the 1840s had only a contributory role in that change (Pringle 1963:192). The same complex of causes is found in the destruction of pre-colonial societies in the Americas. Given the introduction of European diseases the rural population of the coastal areas was rapidly decimated and the collapse of the Japanese sugar industry in the depression of the 1930s. More recently, the Sahelian drought of the early 1970s and its current recurrence have brought to a possibly permanent end the nomadic over-utilization of a semi-arid environment, but without mortality as severe as occurred in a comparable drought earlier this century (Caldwell 1979). Recent attention to the way climatic conditions which prevail in the 1950s and 1960s could facilitate reoccupation of the area at its pre-drought level has not succeeded under the same human use system as before.

Examples could be multiplied, but the point of this digression is simple. Periodic events created by natural fluctuations, or economic cycles, generate crises that may trigger overdues changes, but it is the major event such as the impact of a new socio-economic system that generates fundamental transformation, and perhaps total destruction of the pre-existing system. The destruction may involve depopulation, or its converse. The role of natural processes is subordinate to that of man-generated forces in the sense that without the latter, the former would not have so devastating an effect. None the less, cyclones, drought, and disease of plants and men become the immediate forces which create dislocations. The role of man-generated forces may be to lay the natural environment open to change which renders any restorability of the pre-existing impossible. This is possibly the real measure of so-called deagrarianization in the Sahel; more subtle but equally deadly which to observe the effects, the replacement of man by sheep and then game in the Scottish highlanders permits the extension of agricultural practices which would make unfeasible the speedy reoccupation of most of the area by crops. In each of these environments and circumstances the human condition and its awareness of the talisang as mata evidence of a much earlier, dreastic transformation.

Unstable, marginal environments, and puri- perized, marginalized regions, are both much more susceptible to destructive transforma- tion than are areas of greater natural and socio-economic stability. Some environments, some locations, some societies, some adaptations are more vulnerable than others both to man-generated transformations and to natural transformations to which they are exposed by man's work. Crisis strikes more severely at those environments and societies which have been rendered most vulnerable to its effects. Negative events have lasting effect in some places than major events in others. These differentiations between places are both latent and in natural environ-
The Piaget study: testing the MB approach

The practical significance of a theoretical argument

The point being made here is theoretical but is also central to MB in a very pragmatic sense. Modern thinking on environment is basically transactional: processes are initiated, and environment is thereby transformed. MB is the concept of constant elements in the man-biosphere relationship, and of transformation rules overriding man, have determined in some cases of the man-biosphere relationship, and of transformation rules overriding man, have determined. Not only in man's mind, but in his social processes themselves, can be impacted so severely by some new force such as colonialism that everything is changed. At the same time, however, it is likely that the new transformation rules will in some way resemble the old because of the strong continuity with the same objects. In eastern Fiji, the pre-colonial structures were concerned with utilization of resources in the context of a shifting regional power base. The new structures that have lately begun to emerge from beneath the colonial order are concerned with utilization of resources in the context of an uncertain external power base. There are changes in both crops and in technology. But resources are modified only in small degree, and island economies are still structured with regard to external relations. The selection of resources, and the impact upon them, differ, but a parallel set of rules can be shown to apply. What this argument is suggesting is that while Piaget's mode of analysis remains applicable to man-biosphere systems and man-biosphere relations, it needs to be re-cast in a context in which certain attributes of the objects themselves remain constant. Man can modify his natural environment, in some cases radically, but the essential elements remain. So also do many elements of the human environment. The end of political colonialism does not spell an end to the structures that exist. The rules are modified, but certain basic elements are not altered.

A completely transactional mode of analysis is therefore not possible, either in the case of human use systems or of man-biosphere systems. In the former case the condition of dependency may even serve a complete replacement of the population. In the latter case the climate, geology, and more important the processes which form soil and provide an environment for the flora on which man depends, also remain.

Relevance of Piaget's structuralism to Piaget, structuralism is a mode of analysis; not a doctrine. If we are to apply it in the context of this argument, however, certain modifications are required. It seems clear that the reaction has been not in between formation and transformation, but also between transformation and destruction. Not only in man's mind, but in his social processes themselves, can be impacted so severely by some new force such as colonialism that everything is changed. At the same time, however, it is likely that the new transformation rules will in some way resemble the old because of the strong continuity with the same objects. In eastern Fiji, the pre-colonial structures were concerned with utilization of resources in the context of a shifting regional power base. The new structures that have lately begun to emerge from beneath the colonial order are concerned with utilization of resources in the context of an uncertain external power base. There are changes in both crops and in technology. But resources are modified only in small degree, and island economies are still structured with regard to external relations. The selection of resources, and the impact upon them, differ, but a parallel set of rules can be shown to apply. What this argument is suggesting is that while Piaget's mode of analysis remains applicable to man-biosphere systems and man-biosphere relations, it needs to be re-cast in a context in which certain attributes of the objects themselves remain constant. Man can modify his natural environment, in some cases radically, but the essential elements remain. So also do many elements of the human environment. The end of political colonialism does not spell an end to the structures that exist. The rules are modified, but certain basic elements are not altered.
still at a very primitive level. It is perhaps remarkable that this is so, in view of man's long-established claim to mastery over nature, but the truth is that real understanding of man-biosphere processes is still only weakly developed, management remains largely a matter of guesswork and control is something that has scarcely begun. Yet the real elucidation of man-biosphere theory must lie in the need to understand and control the impact of changing forces of human origin on the operation of the natural processes which they seek to manipulate and control.

The reconstruction of MAB

This discussion has taken us far away from islands, and it will be as well to pursue a little further before the relevance of the island project is finally evaluated. During 1977 and 1978 the MAB Programme has been undergoing some quite fundamental changes, including possibly final resolution of the place of the social sciences in the Programme and, more importantly, a set of decisions to concentrate on only a few aspects of the original wide programme with its 14 'programme lines'. It is likely that there will be a greater emphasis on problems of the urban environment will emerge in the next stage of the Programme's evolution. Emphasis on the tropical forests and the arid lands is logical in recognition of certain imaginative processes of world development. Whereas events in the 1970s have shown occupation of the latter to be at risk under growing climate variability, the same decade has seen estimates that a 30 per cent increase in the world's arable area is both possible and necessary (Loontie et al. 1977), and this can only come about by large scale clearing of the remaining tropical rainforests. It is therefore imperative that the transformation strategies for these areas be understood and the principles of their management be rapidly established. At the same time emphasis is needed on the problems of those environments in high mountains, while islands are to be viewed more in terms of their role in maintaining balance than as units with common characteristics of their own. This too is reasonable, for mountain environments can be viewed as being part of a single system areal and offer important resources whose management is of vital importance in development regions as well as in others. On the other hand, the Cape Verde Islands suffer the same drought as the rest of the Sahelian region, and the cyclone impact in Fiji is scarcely the equivalent of such impact in the Bay of Bengal. The likely emphasis on urban problems is also timely, indeed overdue in a world that is currently pursuing such rapid urbanization.

A participant observer such as this writer can only applaud these changes of emphasis within the Programme. It is perhaps too early to question whether they are sufficient. It is reported that the initial structure of the Programme seems to have been well accepted and compromise between those who envisaged a biologically-based set of inquiries that would address the International Biological Programme, and those who were firm in their insistence on a shift in emphasis toward the impact of man on environment. The biosphere-based projects, and the island project too, derived their initial formulation from the biological school, as has been remarked above. However, at least some of these projects have now taken a very different direction from that originally envisaged. The present paper would seem to lead to the conclusion that still more radical transformation of the structure of the Programme is required, one that takes greater account of the contrasted structure of human use systems, and focuses attention more directly on the interrelation of man-induced processes on natural processes. A greater emphasis on the effects of urbanization may achieve this result, provided that inquiries are not confined within the immediate limits of the cities. However, the study of interrelated processes is not necessarily well-accommodated within a project structure based on biomes, that is on objects. A greater emphasis on processes on the one hand, and on especially dynamic or vulnerable situations on the other, would seem to provide a more appropriate framework for research and generalization.

This is not the place in which to pursue this discussion further, but it is appropriate that it should be raised at this juncture. This paper has been an attempt to review and perhaps advance the theoretical system of the MAB Programme, to try to locate the problems of integration which the changes initiated in 1974 left unresolved. The argument of this paper has been that one function of a programme is to set the agenda for a programme of research that could not possibly be supported from within the programme in its present form. The two disciplines of anthropology and geography, the latter being in part embraced within Bennett's discussion. None the less, Bennett's conclusion (p. 310) parallels that of this paper: There will be two principal subsectors of concern: human use of natural resources and the ecological consequence of our relationship to other species. These are my principal concern, and the present paper in this collection McLean stresses this vulnerability from the viewpoint of physical forces. Foster stresses the way that the human use system of so many of the world's islands have undergone radical transformation, sometimes repeatedly during their history, points to a parallel conclusion. It seems paradoxical, therefore, that one of the expectations of the island programme was to find 'benchmark' conditions in which adaptive, equilibriums man-biosphere systems could be identified, described and modelled. Although it is true that a few islands have remained remarkably free from external contact until only and even into modern times, it is also true that most of the more successful attempts to apply ecosystem concepts to human populations in their environment have been among small groups isolated by mountains, forests and ice, and not by the open highway or ocean.

There is, however, a sense in which even the heavily impacted islands can provide 'benchmarks' for comparison with more 'open' conditions elsewhere. Since contact with islands is of necessity limited to practical but only occasionally mutually intermittent, and furthermore it is possible to increase living space only by insignificant means, these islands under which the resource base can be defined, where external influences can be measured more accurately and where the territorial span of terrestrial natural processes is both small and sharply demarcated. Adjacent islands are often contrasted, as in both Fiji and the Caribbean, so that it becomes possible to describe and even quantify the intervention of human and natural processes and events in a manner that is more difficult in sites on continuous land. From this point of view it is of advantage that island conditions differ only in degree from those of mainland areas of comparable human use system and natural environment. The study of islands can have global value, as well as being important in aiding resolution of the development problems of the islanders. Long before the MAB Programme was conceived, Queen Mah was the mischievous fairy who, in the folklore of the British Isles, put dreams
into the winds of men. Modern folklore would have it that islands are the places where dreams come true. Dreams however, are dece-
itive, and the realization of reality obscure.

The early expectations of the MAB programmes from the island project were cer-

tainly high, yet the context in which the programme was to contribute to the wider field of establishing greater understanding of human-biosphere interactions.

The theoretical system advanced in this paper may also be only a dream, but hopefully one with some relevance to the real world and its acute and pressing problems.

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Formulating guidelines for population programmes and environmental management in small island regions

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INTRODUCTORY NOTE

This paper is written by the two authors separately, but in collaboration. The first part is by R.D. Bedford, who discusses the problems of population policy and the second, third and fourth parts are written by H.C. Brookfield. Bedford who turns to wider implications of the introduction of environmental issues into planning, the planning problems of Fiji and the specific issues which involve the outer islands. In the fourth section, problems highlighted in the whole discussion are dealt with and certain suggestions are advanced concerning policy for regional - or small country - development, and the place of environmental and population planning within such policy.

I. ISSUES OF POPULATION POLICY

(R.D. Bedford)

GENERAL CONSIDERATIONS

Over the past decade understanding of the 'population dimension' in small island countries of the South Pacific has been advanced a long way by intensive research into levels and patterns of fertility, mortality and migration. Important gaps still exist, and scholarly debate continues over the causes and consequences of recent changes in the three demographic processes. Further scientific inquiry into aspects of population change in the region is essential, but it can no longer be claimed that there is a real shortage of information on contemporary demographic developments, readily available to planners and politicians. As one planner stressed with reference to an important policy issue in parts of the south Pacific: 'There has already been enough research done ... to prove an urbanization problem exists. We know why rural-urban migration takes place. To call for more and more research to be carried out before anything can be done about it is to opt out of a commitment. It is now time to do something about it' (Sellers 1976, p. 11).

Reasons for the slow development of population policy

The short- and long-term effects of two particular trends - high rates of natural increase and the rapid population growth to which Sellers refers - have been matters of official concern in various South Pacific countries for a number of years. Containing the rate of population growth to less than two per cent per annum, and slowing the drift of manpower from village to town are emphasized quite frequently in development plans as being necessary conditions for the achievement of projected social and economic goals. Yet while official recognition of the need for government intervention to control the direction of certain population trends is widespread in this part of the world, explicit population policies are rarely to be found in planning documents.

Absence of precise policy objectives or

clear statement of the means by which these will be achieved are hardly surprising given certain features of the population dimension. In the first place, the redistribution trends do not lend themselves to easy manipulation in the short term. As the author of an earlier inquiry into migration has suggested, the implications of rapid population growth noted some years ago (Bavello et al., 1971, p. 14): The time disposition of action that affects population is very likely to exceed the term of public office of the policymaker or planner. This means that the rationale for public policy on population must be so clear to the citizenry that the policy's life is not dependent on the term of its political sponsor. It should also be noted that, except in certain quite specific circumstances, such as controlling flows of immigrants entering a country or carrying out a mass vaccination campaign to reduce the incidence of particular diseases, the short-term political benefits from population policies are not likely to be perceived as being very great in countries where governments must point to significant (and obvious) achievements every three to five years in order to win the confidence of their electorate or to retain in office. Bymer (1975, p. 14) drew attention to an important reason for the slow development of population policy when he commented that 'the art of developing effective economic, social and political instruments to achieve the desired results is still in its infancy'. There is nothing new about government intervention in the population planning arena per se. As Morley (1977) has noted in the context of Singapore (1977). To these writers, population policy spans all governmental actions or plans which, whether intended or not, may have the consequence of direct influence on the composition and, to a certain extent, on the general well-being of human populations. As Robinson (1975, p. 2) points out, this definition rules out the development of such values relevant to the point of becoming meaningless even if they do have the virtue of drawing the policymakers' attention. This is precisely the case with the demographic consequences of all planning decisions. In a sense, all of the policies of any government which contribute to the welfare of its people could be classed as population policies. But as Stacey (1977, p. 106-107) emphasizes, population policy involves considerable confusion results from defining policies as including questions that in fact influence demographic trends but that are not taken into account by the policymaker ... The mere identification of actions that influence population does not make them part of policy. Without denying the importance of anticipating and understanding the effects which a wide range of social and economic policies can have on the three demographic processes, our brief overview of the discussion of alienation in small islands is confined to those strategies which are explicitly intended to change the pattern or level of fertility, mortality and migration. Following Simms and Saunders (1975, p. 8-9) - population policies are here seen as having the following characteristics: - they are public policies; that is, they represent governmental decisions bearing on the allocation of scarce resources for population; - they are national in scale and intent, but implementation may be decentralized and applied differently in different sub-national areas; - they are broad and general in that they are aimed at large segments of national population; they are gross attempts to influence the behaviour of large numbers of people through the use of rather limited repertoires of interventions; - they provide for some action mechanism, for some way of achieving the desired change; - they are macro-level in statement and intent, but results have to be obtained through micro-level changes in values and behaviour; - they are always instrumental to some other end; they are means, not ends. Borelson (1971, p. 178) sums up the essential characteristics of such an approach in the context of Fiji: The choices inherent in population policy are best seen as trade-offs among quality of life, economic development and the demographic inter- relationship between the three. The task of population policy is to discern, measure and adjust the effect of alternative institutional or societal conditions - recognizing that some socially cherished values will probably be lost or weakened in the process of realizing others.

The concept of 'population policy' In addition to these more 'applied' problems associated with planning for changes in the direction of demographic developments,

Guidelines for population programmes and environmental management

- Family planning in Fiji

- Recognition that rapidly increasing population could undermine the economy

- Family planning programmes are pressures from within certain countries (e.g. Fiji in the 1970s) as well as from external sources such as colonial governments and international organizations.

- Fiji was the first Pacific country to initiate a nation-wide official campaign to reduce birth rates - a campaign which has gained international recognition for its early successes. This is not the place to evaluate the contribution the family planning programme has made to the major fertility decline in Fiji since the early 1960s. Hull and Hull (1972) and McAlpine (1971) have examined aspects of this issue at length. It is sufficient to note here that in its latest development plan (Central Planning Unit 1975) the government places considerable emphasis on the need to intensify the drive to reduce the birth rate if the planned target of 2.4 children per family is to be realized. This is not enough. The Medical Department's efforts to disseminate contraceptive information and knowledge about family planning has had limited success. But as project case studies in selected parts of the rural hinterland demonstrated, there is a need for more intensive family planning education involving husbands as well as wives. A general feeling among women in the communities surveyed was that men should be involved in discussion with family planning advisers because they were often more opposed than their wives to the use of contraceptive devices. Many husbands simply forbade their wives to use the pill, loop or to have tubal ligation. Although reference is made in the latest development plan to the importance of doctors and medical officers explaining to men the family planning services available to them, the main emphasis of the campaign over the next five years should be to convincing more couples of the desirability of spacing their births and having smaller families.

While concern with influencing the fertili-
ity behaviour of the reproductive women is essential, new initiatives are clearly needed. In 1975 a Senate Standing Committee on Popula-
tion trends recommended, amongst other things:
That the Ministry of Education offers contraceptive instruction, education for parenthood and sex education to both secondary school pupils and the pub-
lic.
That Parliamentarians and other leaders be encouraged to actively associate them-
self with those motivational and education-
al aspects of family planning.
That the subjects of contraception and family planning be specifically included in the curriculum for nurses and medical students.
Education has a very important role to play in family planning and child and maternal wel-
fare, and Fiji’s planners have appreciated that it will take a tremendous educational effort to extend the programme into the less receptive sections of the population.

The problem in the small island periphery
In the small islands of Fiji’s eastern periphery it is not uncommon to hear strong pro-natalist sentiments expressed by residents. Large numbers of young, single and married children and young adults has led to a perception of 'nest-
ging' communities. In these situations child-
birth is encouraged rather than discouraged. In addition it has been impossible for the Medical Department to service the more isol-
ated islands regularly and so maintain an in-
tensive campaign for fertility decline. A recent initiative which could go some way to promoting the use of contraceptives in small islands is the UNFPA-sponsored ‘Family planning’ which went into service early in 1976. The basic aim is to create a greater awareness of family planning in all parts of the country (including those where populations are increasing very slowly because of the direct and indirect effects of net emigration) while providing essential maternal and child health services to the outside islands.

As mentioned earlier, a major objective of many Pacific governments is to slow the drift of population from rural to urban areas. This is partly motivated by rising levels of urban unemployment, but a major consideration is to encourage greater participation (and hence productivity) in the economy. Policies specifically designed to achieve a reduction in the drift to towns in the short-term will be difficult to implement, because of the rigidity controls over the individual’s freedom to move. But are possible - and practiced - between communities, but not within the coun-
tries. A more realistic strategy could be to facilit-
ate the circulation of population between vil-
lage and town through the development of a more regular shipping service linking small is-
lands to the cores. For certain parts of the rural Pacific, a relatively stable popu-
lation of small and medium-sized rural settle-
centres and a range of employment oppor-
tunities in as well as outside agriculture, is not a feasible objective. Rather than attempting to provide jobs and other attractions to hold the populations on every small island, a more practicable objective might be to promote active circular migrat-
ion between local villages and urban centres on land.

As a result of extensive net out-migration from areas like eastern Fiji there are now two components to any island’s population - one resident in villages on the island and the other in towns elsewhere. Interaction between the two is fostered, in large meas-
ure, by villagers who periodically come to town seeking short-term employment or medical treatment, selling handicrafts and food, pur-
chasing supplies or visiting friends and rel-
atives. In addition, children from the is-
lands who are receiving their secondary edu-
cation in schools located in the towns period-
ically return to their village homes during vacations. This circular migration not only ensures that contact is maintained between different groups comprising an island’s de-

diverse population, but is also a most important process underlying contemporary social and economic change in the periphery. Infusions of money from outside the island has led to a large part of the Income to pay for food im-
ports, houses built of permanent materials, school fees and so on. In addition, more intensive rural-urban interactions has led to the discovery of new marketing opportunities for certain kinds of products and these, in turn, has stimulated some diversification in agriculture and local handicraft industries.

For various reasons the opportunities for major agricultural and industrial development on small islands are relatively restricted. Mining and other mineral resources are negligible, and areas with badly eroded soils or already degraded as a result of overgrazing and overfarming are limited. Soil erosion, poor soils and inadequate water supp-
plies place severe constraints on large-scale agriculture. As a result, the ‘ecological footprint’ of a small island’s economy would be to promote active circular migrat-

II. ENVIRONMENTAL PLANNING AND THE OBJECTIVES OF MAB

APPROACHES TO DEVELOPMENT PLANNING

In the words of Waterston (1969, p 26) the objectives of all development planning may be described by the formula:

\[ \text{overriding objective} = \text{acceptable growth} \times \text{objective for society} \]

This formula implies the importance of identifying the basic objectives for society, whether of economic or social nature, and ensuring that the planning measures are directed towards achieving these objectives. The formula has evolved over time from the concept of 'development planning' to the more recent concept of 'sustainable development', which recognizes the need to balance economic growth with environmental and social sustainability. The formula is now expressed as:

\[ \text{development plan} = \text{overriding objective} \times \text{growth rate} \times \text{sustainable development} \]

Three main levels of planning can be dis-

1. Strategic planning, which is relatively long-term and focuses on broad goals and policies. This level of planning is concerned with identifying the key issues and challenges facing a community, region, or nation, and developing strategies to address them.
2. Project planning, which is more focused on specific projects or interventions. This level of planning is concerned with designing, implementing, and evaluating specific initiatives to achieve the goals set out in the strategic plan.
3. Operational planning, which is concerned with the day-to-day management of the organization or project. This level of planning is concerned with ensuring that the project is delivered as planned, and that it meets the needs of the community or client.

Methods of planning include:

1. Historical methods, which involve analyzing past trends and patterns to predict future developments.
2. Forecasting methods, which involve projecting future trends based on current data and projections.
3. Environmental assessment methods, which involve identifying and evaluating the environmental impacts of a project or plan.
The problem of changing and conflicting goals

It will be evident, however, that the sort of information that is required varies according to the objectives of planning, and to the nature of the different projects in which the project planners and those whom they serve - to be critical. If the simple growth of GDP is the over-riding aim of development, then the range of information that is most urgently needed will concern the incremental capital-output ratios of actual and potential activities, the resources available for the prosecution of those activities with the highest IDORs, and the optimal strategy for diversion of other resources into these most productive channels. If there is also concern with per capita GDP, then information on the composition of the population, its fertility and mortality, and the health and education systems through which family planning schemes can be introduced, becomes of almost equal importance. Once redistribution comes to be allied to growth of per capita GDP as a principal objective, there then arises an urgent need for data on the distribution of income and assets. If the principal concern is the improvement of the human environment, then the great deal of information is required on the structure and productivity of the agricultural sector and of the different activities, the relative roles of formal and informal employment and commerce, and the proper definition of poverty in the context of the country concerned.

Fashions have shifted through time in development planning, creating successive new fashions in data as new needs have come to be perceived. The contemporary debate over urban or rural bias in development policy (Lipton 1977) has thrown open new dimensions of the old industry versus agriculture argument, especially as it has been tied to a more modern concern on the relief of poverty as a primary goal (World Bank 1975). It continues to be debated, for example, whether urban or rural areas are better off than the rural poor, and the significance of subsistence production in evaluating rural poverty levels is an issue that is far from being finally resolved.

Most of this dearth of information concerns the facts of change. The UNDP/UNFPA project made great efforts to have its first report presented to the Government of Fiji by March 1977, less than eight months after departure from the field. And by which the informal sector becomes a major element in the economic life of many nations - to cite only three areas - we have an abundance of theory, some of it well-tried and tested, but yet we often know too little to be able to propose sure remedies for particular ills. In the listed recommendations of development plans, the intensification of research and data collection on what works and what does not is among the most important proposals incorporated within many a proposed strategy for development.

INTRODUCTION OF ENVIRONMENTAL CONSIDERATIONS

If the situation sketched above holds for the present state of development planning in the economic and social fields, it is perhaps not surprising that so little headway has yet been made with the introduction of environmental considerations into planning for developing countries. Even though the management of environment achieves mention in a very great number of reports, and specific proposals are made in some, it has not yet become a dominant item. Whereas the regional development question has advanced rapidly from the bottom of the priority order to a much higher position, for example in the Donkfeld (1979), it is unlikely that we shall see environmental management as a principal objective of planning in developing countries in the foreseeable future. The basic reason is simple, and emerged clearly in the U.N. Conference on the Human Environment held at Stockholm in 1972: to most developing countries the 'pollution' of poverty, poor living conditions and ill-health is far more obvious a matter for concern than is degradation of the physical environment. While there has been great advance in realization of the link between human and environmental degradation since 1972, the priorities of development in the world's poorer countries are unlikely to shift from poverty to the human condition until very much greater progress has been achieved in the latter.

The connection between environmental management and population control might have been approached through the link between the two. The connection between environmental management and population control might have been approached through the link between the two. The connection between environmental management and population control might have been approached through the link between the two. The connection between environmental management and population control might have been approached through the link between the two. The connection between environmental management and population control might have been approached through the link between the two.
very different scales. At the global scale, one of the most recent and important among the "science-based" or "environmental" agendas is that of Leontief et al. (1977), already referred to in earlier papers. They employed a multi-regional input-output model to derive projections of the whole world economy to the year 2000 and beyond. An optimistic view of this exercise — though one downgraded in significance in the report — was to determine the reality or otherwise of the "inhabition problem" as inhibitor to growth. Some very simple assumptions were made. A maximum standard of pollution abatement was provided by the cost of such abatement in the United States in 1970, and this was estimated to have cost between 1.4 and 1.9 per cent of GNP. It is then assumed that developing countries can afford to do without any pollution abatement until their per capita income rises above US$700, and that they need apply only a low level of control until per capita income reaches the level of US$2000. A great number of unknowns is freely admitted. No account is taken of pollution of the oceans, and the problem of erosion is explicitly ignored. Despite this, it is predicted with sublime confidence that the pollution-abatement measures no barrier to accelerated development.

The same exercise also contains other assumptions. Accelerated development calls for extremely high savings rates in most developing countries involving a remarkable degree of investment out of consumption. It also calls for emphasis on heavy industry. To feed the population of the world in the year 2000, most of the arable land can be increased by 30 per cent, and that large further increases in crop and livestock productivity should result. Such assumptions are incredible to many commentators, many of whom add that even if such targets could be attained they will pose environmental problems of an order not met at all in Leontief's inquiry.

Since much of the problem lies in Asia, the results of the second Asian Development Bank (1977) survey are therefore illuminating. Between the mid-1960s and the mid-1970s the supply of irrigable land began to emerge as a constraint to the expansion of rice cultivation in several parts of the region, so that improvements were achieved partly by a shift toward maize, and more importantly by improvements in yield through the introduction of hybrid varieties and technological intensification. Because of dietary preference and deliberate policy, the significance of root crops declined, even in Indonesia where they represent an important part of the diet. The total cost to be en-
forced ... What is needed is a staff of "rural guards" ... to persuade and warn farmers to obey the regulations, and if necessary to prosecute.

Platiud and reality

The closer we approach to the local level, the greater and more clearly does the reality of the environmental problems of rural areas in developing countries emerge to light. The Kenyan example could be widely paralleled in Asia, in Latin America and in the Pacific also. The problem of environmental management is integral to development planning, not only in agriculture as illustrated here, but throughout the whole range of development. It cannot be written away in terms of a tolerable percentage of GNP, or as something that can be ignored until sufficient wealth has been accumulated to afford abatement. Nor can it be treated as a mere footnote to strategies based on growth, with or without redistribution, with or without a poverty focus. Environmental planning, emphasizing management rather than conservation, is as integral to development planning as is population planning. Indeed, the major pragmatic task of the MAB Programme is to turn this platitudes into reality.

ENVIRONMENTAL PROCESS AND PLANNING

One open and environmental planning

The time of development plans is determined in various ways: by the life-span of elected governments; by the expectation of return of investment; by the non-traditional five-year span inherited from the Soviet Union; by the longer-term target dates such as the one becoming increasingly popular — the year 2000. Elements which enter into predictions, whether for indicative or directive purposes, are the environmental ones as well; even if not testable. It is possible to incorporate population and workforce projections within development frameworks, since although the stochastic element grows larger with distance from the last fully- and confidently predictable stage of the human life cycle are variable only within known limits. Planning of new investment programmes as far as possible in terms of years of the well-tried, if questionable, device of cost-benefit analysis. The multiplier effect of a new investment is also capable of quantitative prediction. It is possible to build into the temporal span of the product cycle, and the time lag between invention of a new process and its widespread adoption. All these are subject to large error, and there have been many errors (e.g. Blaug 1971). However, anything to do with environment and environmental processes involves problems of an infinitely more intractable order.

Any determination of natural resources is the easiest part, yet this requires to be related to technology and needs. Land resources can be described, analyzed and quantified by means of established methods, but their evaluation presents problems, as Latham and Denis show in his collection. For example, the fact that some of the most densely populated areas of Papua New Guinea are shown by existing land assessment surveys to be unsuitable for agriculture suggests the need for some re-evaluation of land assessment methods. Living resources are much less determinate, for they migrate between ecosystems. Fossil resources are finite, but their availability is determined in the short term by exploration, its cost, and the demand. Thus availability of all resources is a function of demand, and its qualitative nature, as well as of supply.

Human activity and ongoing environmental processes

Where we are concerned with the impact of human activities upon ongoing environmental processes the problem becomes far more difficult. We have a century before us. The effect of deforestation appears in salines accumulations on the lower slopes. It can be stated with certainty that clearance of forest from a catchment area cannot be reversed and will accentuate erosion. Greater downstream flooding can be described as inevitable, but there is no reason to believe it will be catastrophic. Quite possibly, nothing serious will happen for several years, and the timber income plus the products of agriculture and industry will be regarded as a positive benefit, outweighing the uncertain risk. When exceptional meteorological conditions produce flood- ing whose cost far exceeds the total gain, this can be interpreted as a "natural event", and it is easy to persuade decision-makers that the scale of the event is a man-made phenomenon. Where changes such as rising sea levels, changes in the extent and variability or increasing drought are involved, the external events override human prediction.
None the less, where and when such changes are known and can be predicted, or anticipated, planning and development is essential in order to avoid catastrophe.

Importance of catastrophic events

Catastrophic events are not only important for their own sake, but also because they reveal maladjustments that might otherwise remain concealed. It seems unfortunately necessary for people to suffer grievous loss before such untoward developments as close occupancy of a coastal liable to erosion, over-intensive use of a semi-desert margin, or the release of noxious elements into the atmosphere or hydrosphere, are appreciated for what they are. Without so-called natural disaster, environmental disturbance can continue for a very long time, producing slow deterioration and slow increase of hazard, without either attracting attention or prompting any remedial action. While it is true to say that a disaster represents 'interaction between extreme physical or natural phenomena and a vulnerable human group' (Lewis 1977, p. 9), it would be more true to say that natural disaster represents interaction between ordinary, if violent, environmental phenomena and man's failure to regard the probability of such phenomena.

A digression on disaster relief and insurance

There is currently a great concern with disaster relief and with the possibility of insurance against disaster, and in so far as there is practical experience of environmental planning it lies in this area. While this is a clearly visible area of interaction between environmental processes and man, it escapes the probability calculation of the chance of such phenomena. This was presented as a theoretical argument in the preceding paper, but it is equally apposite in a pragmatic context. To move the argument toward the Pacific islands, we are dealing with a region in which man and human processes play a role in the disaster process. This area is the only region of the world where the disaster process is not limited to one human activity. Generally, the risks for primary production are most visible by the spread of industrial fishing though in parts of the region there is also pressure on timber resources. In every territory there is an effort to persuade the people to shift further along the continuum from subsistence to full-commercial production and employment. Locally, there is great range in population trends, from rapid increase under conditions of already high population density or, rather, concentrating population under conditions of much lower density elsewhere. Thus external and internal conditions operate against the variables of natural environment and the processes of this island, but no two of which can be regarded as exactly alike. General principles can therefore be enunciated only at the maximum level of abstraction, and even then the nature of any specific principle must combine the application downward of broader principles and the generalization upward from a detailed case study. Fiji, the part of the paper has thus far argued in general terms; it now moves to Fiji as a national representative of a small but particular class of nations; after a general review it turns to the particularities of the eastern islands with which the paper was concerned; finally it turns again to generalities which will, hopefully, be of wider application.

III. THE EASTERN ISLANDS OF FIJI

(M.C. Brookfield)

BASIC CHARACTERISTICS OF THE FIJIAN ECONOMY AND POPULATION

Fiji is correctly described in a recent World Bank (1977) report as a small country of sparse population. Its 18 000 km² carry fewer than 400 000 persons, including a density far lower than that of Tuvalu and the Gilbert Islands to the north or Tonga and Western Samoa, the two nearest island countries of the Caribbean. Fiji is also a 'core country' within its region, more highly urbanized and industrialized than its neighbours. Its principal city is not only larger than any other in the south Pacific islands, but is also an extraterritory part of some regional importance, and the source of most of the manufactured imports, other than processed products of primary origin, which circulate within the south Pacific region. The tourist industry is more highly developed in Fiji than elsewhere in the western Pacific, but the economy still depends mainly on agricultural exports—attracting even more foreign investment than the more common regional expert, copra. It depends heavily on and increasingly on imported foodstuffs, the proportion of its imports consisting of food having risen from 10 to 25 per cent in a decade up to 1975. It is therefore representative of a country with the Seidman Development Bank (1977, p. 141) describes thus: countries can be considered as being vulnerable to short-run changes in world economic conditions with respect to the domestic availability of essential materials such as food and fertilizer, and the absence of some basic and other important items from overseas. Countries which need to import much of their food, and at the same time are dependent on the export of one or two agricultural commodities to provide most of their import purchases, are more easily disadvantaged by sudden movements in world markets than countries which produce nearly all their own food and have a diversified range of exports. The vulnerability of Fiji can, however, be overstressed. The principal agricultural export—sugar—has been reasonably well protected by trading agreements for the last 30 years, and recently copra has also come under the support of the Sugar Agreement and the ARS system negotiated in 1973. The growth of tourism and of the service industries has provided a strong alternative to sugar, so that real GDP per capita reached a level of US$900 (US$750 in 1975), with a sustained rate of growth supported both by economic health and by a decline in the rate of population growth from over three per cent to under two per cent per annum in a decade. Moreover, agricultural production has grown at an annual rate of less than one.
Guidelines for population programmes and environmental management

The FIJIAN PLANNING DILEMMA

The second half of the 1970s have become a critical period for the direction of planning in Fiji, where conflicting internal goals have been broadcast in a constant debate between external reports. Whereas early planning in the 1960s depended heavily on the full development of natural resources (Burns, Watson and Peacock 1960), this strategy swiftly underwent modification toward emphasis on a high rate of growth, with tourism assumed as the leading sector by the end of the 1960s. By the early 1970s, urbanization and the state of the rural economy were coming to be seen as problems and the 1971-5 development plan proposed some corrective action, though still within the dominant objective of maximizing growth of national income. In a mid-term review (FIJ 1971, Minister of Finance 1974) recorded growth only 'fair success', but also noted that the problems of urbanization had grown and cast doubt on the success of rural development. By 1975, however, the rural economy was in need of much greater attention to redistribution and greater national self-sufficiency. A regional planning subcommittee of the Fijian administration was requested from UNDP, and the Unesco/UNIPA proposals for planning-oriented research in a peripheral area of partial national concern were welcomed as contributing to the same goals.

Unfortunately, the climate of planning was quickly changed by the spread effects of the world economic crisis which began during the last months of 1973. The weakness of Fiji's 'energy-supply position — wholly dependent on oil — was immediately exposed and dependence on imports also made the country vulnerable to imported inflation, which touched a level of 17 per cent on an annual basis at its peak. The tourist industry suffered a sharp setback in its rate of growth, and throughout the later months of 1974 the position of the state and of farmers were extremely difficult until a more stable level was achieved through international agreements in 1975. The employment position worsened, and the view of Fiji as having a labour-surplus economy, stated by Fisk some years earlier (1970, p. 63), was now overturned, luxury planning emphasis in at least some quarter toward the problem of employment generation. Though Fiji survived relatively well, the rate of economic growth was checked to a level of around two per cent in 1974-75 (World Bank 1979). The lack of success of the economy were exposed rather clearly to view. To some, the redistributive goals which had grown out of discussions in early 1970s came to appear as luxury; greater emphasis had to be placed on further reduction in the rate of population increase, on growing output to provide employment, and on new investment.

The Urban Bias or Rural Bias?

It is, in retrospect, unfortunate that two groups whose reports first became available during 1976, and were published in 1977, adopted different approaches to the problem which — on the surface at least — appeared to be diametrically opposed. Again in retrospect, it would appear that their masters in New York and Paris forced them to come together and produce an agreed set of recommendations which should have been possible since there are in many countries complementarities. The breadth and vision of the ILO studies survived their sponsors, and the recommendation (ILO 1972) might well have served as model.

The UNDP regional planning group (UNDP 1977) saw employment generation as a major problem and recommended a variety of measures to solve it. Their recommendations were to be pursued for economic and social workers throughout the remote islands and the rural areas which will still be the desired home for many Fijians.

The Unesco/UNIPA Project (1977) was bound by its terms of reference to pay attention to the economic and social recommendations; however, they found it impossible to avoid consideration of the whole national economy. In the view that they took of rural development was very different from that of the Unesco regional planning group. From a base in the outer islands, it was not possible to envisage rural development as a leading sector, in the way that it is so envisaged in Malaysia or the interior of Brazil. None of the less, they dissented from the regional planning group's report. Urbanization, to the Unesco/UNIPA group, provided an opportunity to restructure the rural economy of quite large areas away from dependence on export crops in which their isolation and small scale gave them little comparative advantage, and toward supply of the home economy in which their advantages could be exploited to the full by means of a more diversified rural economy. Other parts of the periphery, better endowed with natural resources, could be developed for a more diversified export
economy through agro-industry, focused especially at the new industrial centre at Savusavu in Vanua Levu proposed by the UNDP group.

Fundamentally, the UNESCOf/UNEP group sought opportunities for re-vitalization of the rural and coastal communities in partnership with the growth of towns. And their terms of reference included the larger islands of Fiji, especially those for which the UNDP group could have said much more. Essentially, they are in agreement with the subsequent World Food Group in arguing that the longer term prospects of economic development for the 1980s are reasonably good considering the potential for developing natural resources, and assuming continued efficient management of the economy. The major areas of growth in the 1980s for which plans are already underway are: forestry, mining, hydro-electric power generation, and fisheries.

With the expansion of the Fina Scheme begun in 1972, forestry should become a major source of foreign exchange during the 1980s, serving as a basis for a variety of processing industries and creating employment in the rural areas. Moreover, the project would add that all these developments, rural and urban alike, create potential for fuller re-orientation and diversification of agricultural production, and for better use of the country's endowment in natural resources. All the proposals were designed to provide the infrastructure, create the channels of extension and marketing, and economic and social institutions in the way of such active rural participation in the achievement of national self-sufficiency. These developments, conflict, but is a question of bias. Different groups see different aspects of the same problem. The UNESCOf/UNEP group is recognizing the strong urban bias of Fiji's current thinking, and especially that of its rural population as Bedford demonstrates with convincing evidence. But the UNESCOf/UNEP group, in common with other observers and the authors of the 1976-80 development plans, are also correct in stressing the large endowment of natural resources and the low intensity with which they are currently developed. Fiji may have a labour-surplus economy, but it also has a resource-surplus economy in terms of present perceptions. Is the task of the designer of development guidelines to go along with current perceptions, or to seek to change these perceptions? Is the latter closely related to objective realities?

This is one of the fundamental questions posed by the present collection.

CONTRASTED VIEWS CONCERNING OUTER ISLANDS

The outer island problem

If, as is suggested above, the vulnerability of the Fijian economy is capable of being overestimated, so also is the small slice of the country. Size is relative to the cost in time and money of intercommunication within a country, and when one is in Fiji the impression quickly gained is of being in a large country, not a small one. Travel is not easy; many areas are difficult to reach and even more difficult to leave; Fiji covers a sea-space many times its land area and at an average speed of seven knots it is more than two days' journey from one end of the country to the other. Due to delays, it can, in fact, take weeks to travel from the Yasovas to One-i-Lau, and even within the larger islands there is no sense of easy intercommunication. For the outer islands, served only by small ships at infrequent intervals, two or three hundred kilometres constitute a moat.

As is stressed in other papers in this collection, the outer islands of Fiji contain a range of resource diversity which is par-alleled, but is not easily exceeded, in other parts of the world. Externally, it is easy to view them as a single group with a single set of problems. When one is in the outer islands, however, each island has its own group of problems and its own sets of constraints. The element of scale entering into the design of guidelines for development planning is nowhere more clearly illustrated.

An external view of the islands

The eastern islands of Fiji are only a small part of a small country, even though they spread over half the sea-space occupied by the archipelago. Fiji's total land area of a little under 1500 km², these islands carry 6.6 per cent of the nation's population (including a reasonable Indo-Fijian element) on some eight per cent of its land. Formerly the population shares was much higher, and the rapid relative decline of this important element in the regional situation. The eastern islands still produce about half Fiji's co-para exports, but the share of co-para in domestic co-para exports by 1976 has value has ranged only between 14 and 14.7 per cent between 1965 and 1975; no other export commodities of significance are produced within the region, so that the share of the eastern islands in Fiji's dom-estic production is declining in a manner that is similar to the share of the population in the total population, sometimes less and seldom more. Some of the islands contribute significantly to domestic sup-plies of root crops and especially the national stimulant - yasawa. While no quantita-tive data are available regarding co-para share in the total supply is probably well over ten per cent by value, and larger if the island share of the Korotogo south of Suva, is also included. While the national share in dom-estic supplies has certainly shown a declin-ing trend, the opposite is true of internal supply. However, Couper's (1967) comment that the potential production of these is-lands for the national market is greatly con-strained by inadequate transport remains equally true more than a decade latter.

Measurement of the value of these islands to Fijian economy, society and politics is a matter of perception, not of quantification. Except from the one point of view that was stressed in UnescOf/UNEP (1977) - that of comparative advantage in supply of the national market - they are of declining significance by all quantitative measures. The parallel UNDP project issued a discussion paper early in 1975 suggesting that the country could ill afford its expenditure on the maintenance of services at high cost to these islands, and they were not alone in their view.

Yet these islands are not only of histori-cal and sociological importance. As Bedford shows above, still regarded as 'home' by a significant proportion of the Fijian popula-tion now and it will be so in the future, they have national value because of the large proportion of the total national space that these islands occupies becomes much greater significance in view of the new 370 km (20 mi) 'exclusive economic zone' with Fiji, is immensely larger then it would be if there were an extension of these islands. Their sparse population also con-trasts rather markedly with the much denser occupancy of the country to the east and north - Tonga, Western Samoa, Tuvalu and the Gil-bert Islands. Yet, are their resources in-significant, or without distinctive value?

Comparative advantage and the eastern islands

The wettest and cloudiest part of Fiji lies in a broad belt across the east of Viti Levu and the south of Vanua Levu, and includes some of the larger and higher of the eastern islands, such as Koro and Taveuni. However, the latter two islands are geographically young volcanic peaks rising from mineral ferty-

ity and - from the project's investigations - unusual stability under cultivation. Their land area includes some of the most fertile arable land in the archipelago. The remains of the eastern islands have higher sun-shine levels, with liability to drought in-creasing toward the southeast. No part, how-ever, is so dry in the mid-year months as the dry zone of northeastern Viti Levu and northern Vanua Levu. The main concentration of urban population in Fiji is found in the wettest and cloudiest part of the country, where an urban population now approaching 150,000 may well reach 400,000 or more before the end of the century. The close hinterland of this population has poor soils, high rainfall and low sunshine levels; the islands, on the other hand, have much more favourable growing conditions, and it was for this reason that the UnescOf/UNEP project recommended infrastructure investment in improved shipping which is the principal desideratum required to enable these islands to play a much larger role in supply of the growing urban market. Extension work and re-search are also necessary, but very wide-spread. Fieldwork has been done by island farmers in an area for more than twenty years, initially with no advice or support from outside.

At present, most of the best land of the eastern islands is under co-pon, cultivated to the point where it is likely that the project suggested that since crop production in this region suffers a severe 'hinterland' pen-alty. Yet in the future, it would be better to divert this production progressively to the more stable and growing home market for fruit products. The much more favourable situation of the coconut industry in the Windward Islands of the West Indies, which supplies the urban market of Barbados and Trinidad, may be studied closely by Fiji's planners.

The island also command large roof and largest areas which in 1976-80 were quite heav-ily exploited for subsistence purposes, but in other places are little touched. Given the high price of fish in the market, the project commended new initiatives by the Fisheries Division to exploit this resource using the simple methods of drying and smoking, but urged that such effort be expanded by more active provision of access to boats and other necessary infrastructure, including repair facilities.

In other words, it was argued that while
these islands are at a comparative disadvantage in regard to the export market, they have considerable comparative advantage over other areas for supply of the national market with a wide range of its needs. Given the goal of greater national self-sufficiency espoused in the 1976-80 development plan, as strongly endorsed by the World Bank mission (1977), it seemed to the UNESCO/UNFPA project that the proper propagation of the emphasis placed on the EXDP regions on the growing urbanization of Fiji's population was a development plan for the eastern islands periphery designed to supply this growing urban population with some of its needs. For greater use could be made of the ecological diversity of the region under such a strategy than under the present coconut economy, while the creation of a stable production and marketing system would eliminate the dissatisfaction and uncertainty which have been major causal factors in the accelerating emigration of recent years. Along lines such as these, efforts to provide the means of greater development in the eastern islands would not be a waste of national resources at all.

The island level

At the level of individual islands, the problem is different again. The island of Taveuni and Koro have some of the best soils in Fiji, and are capable of great improvement in agricultural output of a sufficient scale to support modest agro-industry, especially on Taveuni. The varied resources of Lakeba do not offer great problems, due to the scale of resource blockage, but this and some other Lauan islands also have considerable possibilities for supply of the national market. On the other hand, the small islands - and especially the small limestone islands are so lacking in agricultural resources that, except where intensification of fishing is a real possibility - there is little that can be suggested beyond welfare investment, and acceptance of the probability of continued population decline. The important point is that these islands need not lose people only to the towns; their people could also use the rich resources of the larger and better endowed islands. As so often, the private initiative of the people from some of the small islands in doing just this - the resettlement of most of the people of tiny Qalalavan on Taveuni, for example - provides empirical evidence that this is a real possibility, not an externally-conceived dream (UNESCO/UNFPA 1977).

IV. DISCUSSION AND CONCLUSION

A NOT UNCOMMON PARADOX

H.C. Brookfield

The condition of excess supply of both resources and of labour - the one based on objective assessment, and the other based on perceptual assessment - is a common occurrence. By objective criteria, most of these eastern Fijian islands are populated well below capacity. On the other hand, they are losing people to the towns at a rate which has accelerated in recent years, and are not viewed by their inhabitants as places capable of offering support for an adequate lifestyle without the aid of external remittances, supplemented by government services provided at a rather high per capita cost.

Under such conditions natural resources are exploited at rather low density. Former skill-intensive cultivation practices are used less and less, and a large diversion of land to low-value uses of production, since plantations is tolerated. Environmental management is not viewed as a major problem, and the possibility that this problem could be transferred to the urban environment, so that job creation is seen as in the context of industry, tourism and services. As Bedford argues strongly in the first section of this paper, change in this condition is a question of education on the one hand, and of conscious planning on the other. Elsewhere the project has argued that scaleable rural incomes are just as important in this context as higher rural incomes, for short-lived boom conditions achieve no favourable result. The national problem of excess labour supply has to be tackled at a national level from the point of view of fertility control, but the regional problem - of which migration is one major element - needs to be approached by strategies designed for particular areas. The first question to be resolved is the degree of urban or rural bias which is to be applied in determining regional policies. Once this is determined, then detailed policies concerning the proper use of land, the provision of infrastructure, productive investment and rural services can be drawn up according to the needs and natural resources of each part of the country. The UNESCO/UNFPA project in eastern Fiji pressed for a strong rural bias on grounds of the well-documented policy of national self-sufficiency. But this basic decision remains to be taken in Fiji, as in many other countries.

The problem in more densely populated countries

Problems of a more acute order arise in countries where natural resources are in very short supply in relation to population. The countries east and north of Fiji provide examples. The Gilbert Islands, for example, face independence in 1979 with almost immediate exhaustion of the phosphate revenues from Ocean Island, a set of crowded atolls producing only food crops and copra, and some larger but roughish-proven islands 4000 km to the east which offer only doubtful possibility for relief. The Gilbert Islands also have an urbanization problem, with 29 per cent of the whole population on Tarawa an atoll with only limited land and water. The Gilbertese, for whom the only substantial landholding is the sea in the surrounding seas, urgently seek possibilities for decentralizing their economy and population. The majority of people to the east are important to conservationists for their bird-life; to the Gilbertese they also are significant as the only import and land resource remaining that lies within their own jurisdiction.

The importance of scale

had British colonial rule combined all its economic and political instruments in the political unit the Gilbert Islands would have become peripheral to Fiji, and their population probably would have been absorbed in Fiji. The indigenous people have been major exporters of copra etc., the principal exports in the pre-war era. Fiji and more recently the people of the Gilbert Islands have to the east are important to conservationists for their bird-life; to the Gilbertese they also are significant as the only import and land resource remaining that lies within their own jurisdiction. Social and economic development has been impeded by the complex internal differentiation in all three demographic variables that can be demonstrated within the island of Mauritius; the response to changes in the economic base, the introduction of malaria and its subsequent eradication, and diversification and industrialization (Brookfield 1959).

Few of these internal events have been, or could be expected to be, of the same political or economic significance as the re-adjustments that follow economic or environmental change. The same is true of the re-clothing of the barren hills with pines. Some indication of the possible consequences elsewhere in the system can already be obtained, but only observation and learning can provide the knowledge that may be applicable, mutatis mutandis, in other situations. Some unexpected consequences of natural disaster
have also been identified, the consequences varying not only in accordance with the nature of the disaster, but also with changes in the external forces and the human use system of the island impacted.

**Conclusions:** A new sort of planning

**To most planners, 'environmental events' are unexpected disturbances which invalidate assumptions made on the basis of mean conditions — or better-than-mean conditions.** Just as population and workforce projections can be thrown away by unexpected shifts in one or more of the variables, so can projections concerning the environment. The lack of full understanding of many of these processes, and the ignorance of many planners concerning what is known, contributes to such surprises.

The real meaning of population and environment planning is therefore the need to anticipate, or at least allow for, the unexpected. This is true at all levels of planning, but is of greatest significance in translating plans to small areas, and to individual projects. The task of designing guidelines for the rational management of island land — or any other ecosystems' therefore breaks down into a series of steps. First is the determination of priorities. Second is an effort to comprehend the dynamics of existing conditions of population and environment. Third is the advocacy of measures which might both serve the priorities and allow for variability and give some guidance in how to deal with the unexpected.

Above all, however, the aim of such a new sort of planning must be to learn, and to go on learning. The Fijian project sought to learn from the past and present condition of a small group of islands, to try to understand the dynamics of the situation, and to make proposals based on existing trends, within the assumption of a priority for rural development. Hopefully, the succeeding Caribbean project, and other PAB projects, can advance this concept of planning much further than was possible in the pilot project now concluded.

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This list includes all publications by the project and its members which have thus far appeared, with the exception of papers in the present Technical Note. Among papers published outside the scope of UNESCO itself, only those with substantive reference to material collected while engaged in the project are included. Brief explanatory notes are added on the principal series. Enquiries concerning project publications should be addressed to Unesco, or to the Editor (Professor R.C. Brookfield, University of Melbourne, Parkville, Victoria, 3052, Australia). However, only limited stocks remain available, and it is normally possible to supply only libraries and official bodies.

The project working papers

These papers were prepared in mid-1976, and were printed for Unesco by the Australian National University, Canberra. Nos 1 and 2, and Nos 4, 5 and 6 were bound together, though separately paginated, so that there is a total of only five volumes.


The general reports

2. Constituted by the present publication.

The island reports

1. UNESCO/Unfpa. Island Reports 1. 1977. The hurricane hazard: natural disaster and small populations. Australian National University for Unesco, Canberra. (Only few copies available.)
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