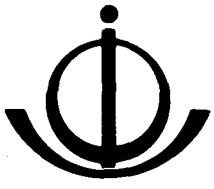
Intergovernmental Oceanographic Commission

Workshop Report No. 56

IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP)

Cleveland, Australia, 24-30 July 1988



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No.	Title	Publishing Body	Languages
1	CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on); Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp.	Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand	English
2	CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No. 20).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish (out of stock)
3	Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock)
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7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
8	Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
9	IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
10	IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish (out of stock) Russian
11	Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish (out of stock)
11 Suppl.	Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
12	Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 28 November-2 December 1977.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French
15	CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
16	Workshop on the Western Pacific, Tokyo, 19-20 February 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Russian
17	Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
17 Suppl.	Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
18	IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No. 4)	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) French Spanish (out of stock) Russian
19	IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5).	Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian Arabic
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
21	Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
22	Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish Russian
23	WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Russian
24	WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock)
25	Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (superseded by IOC Technical Series No. 22)
26	IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
27	CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
28	FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
29	WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981.	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
30	International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980.	IOC, Unesco Place de Fontenoy, 75700 Paris, France	English (out of stock) Spanish
31	Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
32	UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish

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IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP)

CSIRO Marine Laboratories,
Cleveland, Australia, 24-30 July 1988

Edited by D.J. Staples,
P.C. Rothlisberg and S.M. Garcia

SC-89/WS-32

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FOREWORD

The IOC Regional Committee for the Western Pacific at its Fourth Session held in Bangkok, June 1987, accorded high priority to co-operative research projects that are of common interest to the Member States of the region and which require concerted action of interested institutions. One of the projects identified by the Regional Committee was the Recruitment of Penaeid Prawns in the Indo-western pacific region as a regional component of the IOC programme in Ocean Science in Relation to Living Resources (OSLR) in the WESTPAC region. As part of the implementation of the Phase I of this project, the IOC Regional Committee endorsed the offer of Australia to host the Workshop to thoroughly review the work so far done in the past on the prawn recruitment studies and to develop an operational plan that would facilitate the participation of interested institutions in the project with the purpose to eventually establish a co-operative network of institutions in the target area in the region. The Workshop was held at the CSIRO Marine Laboratories, Cleveland, Australia, 24 to 30 July 1988 with the financial support of the following organizations: The Australian Fisheries Service (AFS); the Australian International Development Assistance Bureau (AIDAB); the Food and Agriculture Organization (FAO); the Intergovernmental Oceanographic Commission (IOC); and the South-east Asian Fisheries Development Centre (SEAFDEC). The Report was edited by Drs. Rothlisberg and D. J. Staples of the CSIRO Marine Laboratories and S. Garcia from FAO which is gratefully acknowledged.

Penaeid Recruitment Project (PREP) Workshop
24-30 July 1988 CSIRO Marine Laboratories, Cleveland Australia

Front: Nurzali Naamin, Ursula Kolkolo, Mattana Boonyubol, Corazon del Mundo, Somkiat Piyatiratitivorakul, Atchara Vibhasiri, Kasijan Rominohtarto
Back: Mohd Taupek Mohd Nasir, Peter Rothlisberg, Purwito Martosubroto, Alejandro Yañez-Arancibia, Joel Opnai, Serge Garcia, Derek Staples, Ian Somers, Jose Ordoñez, Tony Courtney, Lui Yean Pong
Missing: Peter Crocos, Bob Harriss, Burke Hill, David Vance

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ANNEXES

1. INTRODUCTION

On behalf of the Chairman of WESTPAC, Dr. Takahisa NEMOTO, Mr. R. HARRISS welcomed participants to the workshop noting that it was the first example of interaction between FAO (SCORRAD) and IOC (WESTPAC) in the region.

He thanked CSIRO Cleveland for its organization of the workshop and for making the facilities of the laboratory available. He further thanked the financial supporters of the workshop:

The Australian International Development Assistance Bureau (AIDAB)
The Australian Fisheries Service (AFS)
The Intergovernmental Oceanographic Commission (IOC)
The Food and Agricultural Organization (FAO) and
The South East Asian Fisheries Development Centre (SEAFDEC).

He reminded the participants that the proposal for this Workshop was endorsed by WESTPAC at its Fourth Session held in Bangkok, June 1987, with the specific objective of developing an operational plan for the implementation of the Co-operative Project on Shrimp Recruitment in the Indo-Western Pacific region. He, therefore, noted that from WESTPAC's perspective, the Penaeid Recruitment Project (PREP), and this workshop in particular, provided an excellent model for other projects in that it involved elements of planning and training heading towards a genuine collaborative research programme. PREP also provided a model which could be expanded further into the WESTPAC region and afforded the opportunity for interaction between WESTPAC and the other regional bodies, particularly IOCARIBE and IOCINDIO.

On behalf of FAO and IOC, Dr. Serge GARCIA thanked all the persons and organizations that had contributed to the preparation and funding of the meeting with a particular mention of the technical support given by Drs. STAPLES and ROTHLISBERG, and for the contribution of Dr. MARTOSUBROTO, Chairman of SCORRAD, during the preparatory mission in February 1988.

He mentioned that FAO had supported the meeting, as recommended by SCORRAD, and hoped that the diligent efforts developed by all the participants would lead to the funding of the regional research network for penaeid recruitment studies aimed at improved management and sustained development of the important shrimp fisheries of the region.

He noted further that, as a natural part of the Ocean Science in relation to Living Resources (OSLR) programme of IOC and FAO, the meeting should identify the environmental parameters and studies which are feasible and needed for the solution of the research problems in front of them.

Dr. Peter ROTHLISBERG (Programme Co-ordinator, WESTPAC OSLR) described the structure and context of the current IOC-FAO/OSLR recruitment programmes of both WESTPAC and IOCARIBE (Figure 1, Annex I)

He then gave a precis of the history of PREP from its inception as a WESTPAC/OSLR component at WESTPAC III in Townsville in September 1983 up to the present workshop (see Annex II for details). He highlighted the role of the IOC/FAO/TRODERP workshop in Ciudad del Carmen, Mexico (April 1986) in formulating the principles of a regional comparative approach, with Penaeus merguiensis as a possible model. The successive endorsements of a preliminary PREP proposal by FAO/IPFC/SCORRAD (February 1987), by IOC-FAO/OSLR Guiding Group Experts (June 1987) and WESTPAC IV (June 1987) demonstrated the support of the scientific community. The last major activity prior and preparatory to the workshop was a mission through the region by Dr. STAPLES (Technical Co-ordinator of PREP, Dr. MARTOSUBROTO (Chairman of SCORRAD) and Mr. R. HARRISS (Assistant to the Chairman of WESTPAC) which identified national co-ordinators, possible study sites (Figure 2), workshop participants and data sets to be processed at the workshop.

2. AIMS AND STRUCTURE OF THE WORKSHOP

Dr. STAPLES briefly underlined the economic importance of penaeid prawn fisheries and the problems raised by their management, particularly in view of the extremely high levels of fishing in the region and the sign of recruitment deterioration in some of the most important fisheries in the region. He stressed the fact that in order to respond appropriately to the questions of the managers regarding resources development, sustained, applied research was necessary.

For the purpose of the workshop, recruitment was defined as the number of prawns entering a given life history stage/habitat. For penaeid prawns, where each life-history stage tends to inhabit a restricted habitat, this simple definition provides a working basis for future discussions. With this definition we can consider the recruitment of postlarvae into an estuary, the recruitment of adults into an offshore fishery or simply their arrival at some depth zone. By definition, therefore, recruitment is a function of the egg production and survival of individuals up to a given stage in the life cycle. Both these components depend on population size, which may be extremely variable due to fluctuations in the environment, and biological factors such as predation.

All the penaeid fisheries of the participating countries, are mature or over-exploited fisheries in the sense that the number of fishing units are probably in excess of the fleet size which can catch the long term sustainable yield. This has come about from the rapid growth in total catch and fleet size resulting from the advent of trawling. At this phase of the fishery, the most important management questions are:

(i) related to the uncontrolled increase of the efficiency of harvesting by gear or effort modification;
(ii) the assessment of whether current yields are sustainable or not; and
(iii) how future technology changes will affect future catches.

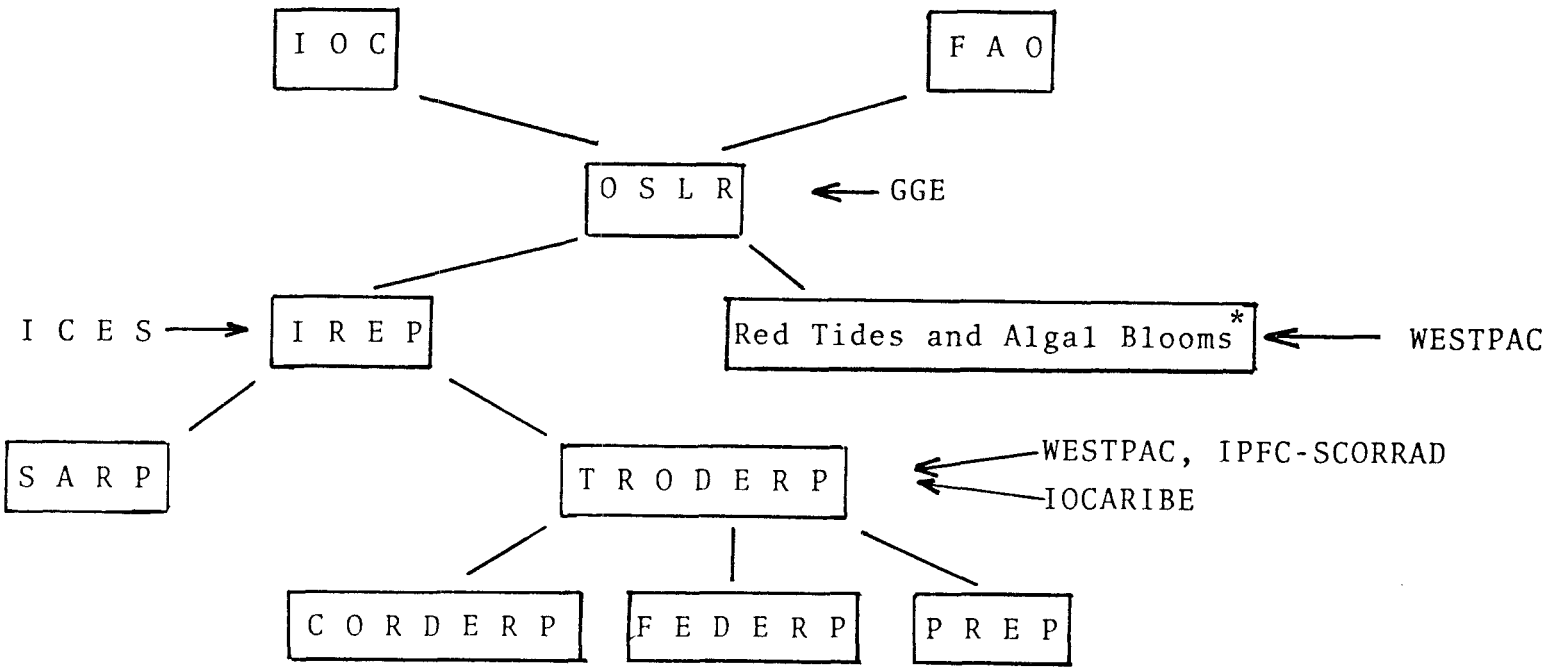

Figure 1 : Organizational structure of IOC-FAO OSLR programme

* This Component is also related to other programmes of IOC, especially GIPME (Global Investigation of Pollution in the Marine Environement)

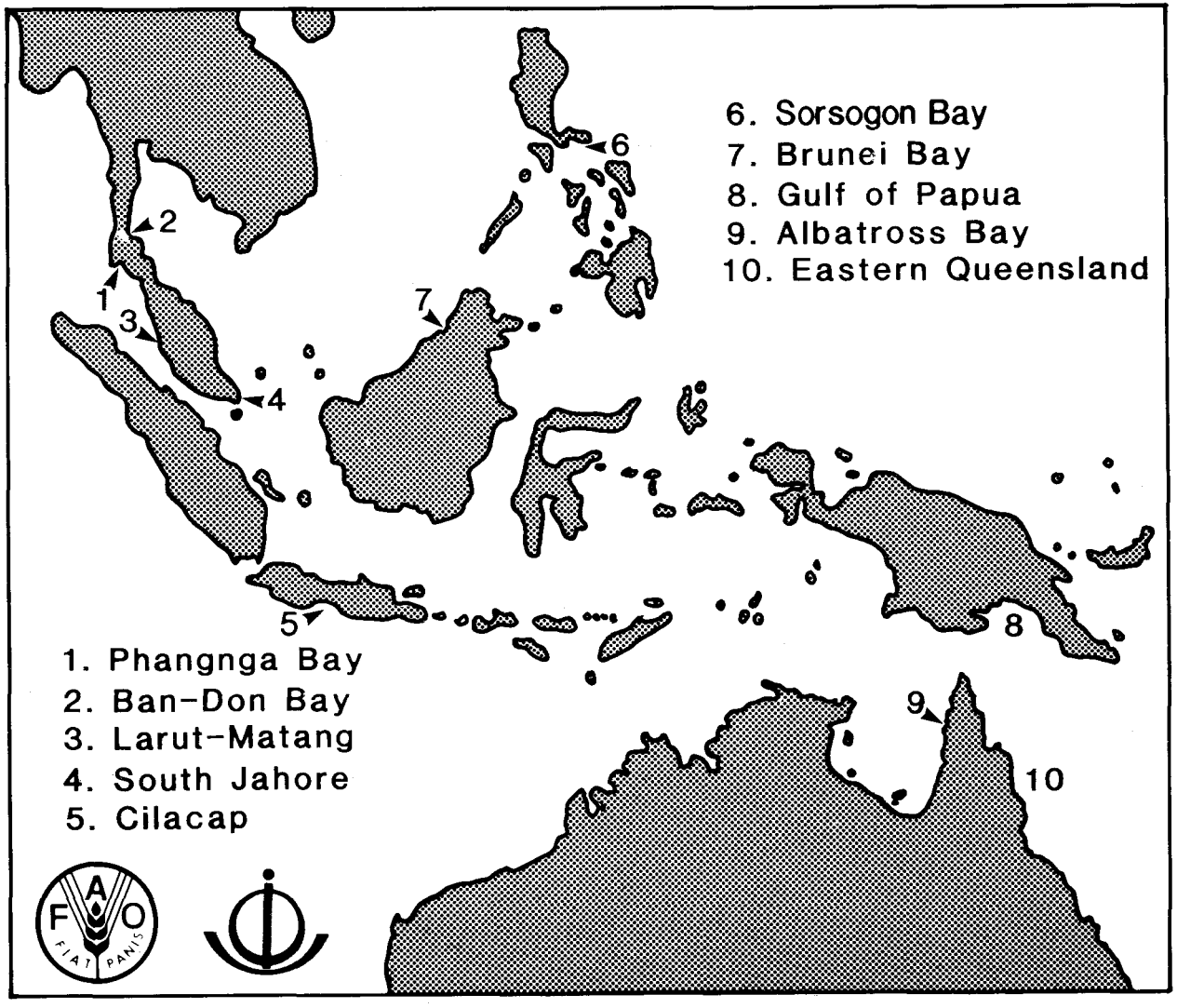

Figure 2. Proposed study sites for the Penaeid Recruitment Project (PREP).

Recruitment analyses and forecasts are the main tools available to the biologist to address these problems. Traditionally, two types of approaches have been used:

(i) Study of biological processes affecting recruitment; and

(ii) Stock/recruitment modelling.

Although both of these approaches have made important advances towards our understanding of populations and their dynamics in space and time, neither has provided the information necessary to answer the major management questions. Because stock/recruitment analyses normally rely on one data point each year, most time series are too short to provide the average response from normally extremely variable data sets.

PREP will attempt to overcome these problems by attempting to analyse survival of cohorts at various recruitment times within years and also by comparing recruitment phenomena of different stocks across several countries in the WESTPAC region.

The main objective of PREP will be to examine and try to separate both the effects of the environment and fishing on recruitment, and provide advice on levels of fishing likely to prevent recruitment collapse. The approaches to be followed by the workshop (programme in Annex III) will be:

(i) Use existing data on Penaeus merguiensis to review the existing knowledge of recruitment of this species at a number of PREP study sites;

(ii) Examine data needs and techniques for data collection and analysis;

(iii) Make geographic comparisons;

(iv) Plan future research; and

(v) Discuss research implementation.

This approach should lead to an assessment of the seasonal patterns of abundance of the different life-history stages, environmental factors and fishing. From these analyses it should be possible to identify critical periods in the life-history and make temporal links between spawning and recruitment. Both direct and indirect methods of estimating recruitment will be discussed along with stock/recruitment modelling, recruitment processes and geographic comparisons. Each participating country will be responsible for examining and interpreting the seasonal patterns and inter-annual variability in their own data sets (National Reports, Annexes 7-12).

3. ANALYSES OF RECRUITMENT DATA

3.1 INTRODUCTION TO DATA STORAGE AND PROCESSING

Before the meeting all participants had sent biological and environmental data to Dr. STAPLES. These data sets were entered into REFLEX (an integrated data manager from Borland Inc.). Participants were provided with computers and trained on the use of this computer package (data filing, retrieval, processing and graphing).

3.2 TREND ANALYSES

Participants processed the time series (both seasonal and inter-annual) of data available of abundance indices of various life stages (e.g. eggs, larvae, postlarvae, juveniles, subadults and adults), catch, effort, rainfall, and other environmental variables for further analysis and comparison. See Table 2 for summary of available data sets.

The analyses of seasonality of life history stages, environmental variables and fishing effort is an essential prerequisite to the analysis of recruitment data on penaeid shrimp. This is easily achieved using such computer graphic packages such as Graph-in-a-box, Reflex, Lotus 1-2-3 and Statgraphics. During the workshop, all graphs were produced from the Reflex package which proved to be easy to use, although the standard of graph produced was very basic. By plotting the monthly abundance of the different life-history stages on the same monthly scale, shifts in the modal abundance were often followed, and the temporal link between life history stages established (See National Reports, Annexes VII-XII). In penaeid prawns where several pulses of recruitment into the offshore fishery can occur each year, it is important to establish the critical periods of spawning and recruitment within a year in order to determine which are the effective spawning periods and what environmental conditions result in successful recruitment into the different life history stages. These within year comparisons of cohorts may highlight important variables which affect the inter-annual variability of recruitment and can be achieved in a much shorter time scale.

The general summaries of the life history timing and rainfall of each study site provided sufficient information, even at this early stage in the project to make geographic comparisons across the region (Table 3). In most study sites a bimodal pattern exists, with two periods of increased spawning, rainfall and adult abundance recognized each year (Table 3). In many cases, the main period of recruitment into the fishery (as indicated by increased adult abundance) appeared to coincide with the larger of the two peaks in the monsoonal rainfall pattern. In the northern hemisphere, this occurred during the period September-January, whereas in Papua New Guinea (PNG), the main period of rainfall and recruitment was 6 months out of phase, peaking during April-July. In northern Australia, where only one wet season occurs each year, although two periods of spawning still persists, only one period of recruitment into the fishery occurs following the wet season which lasts from December to March. Rainfall and river runoff was, therefore, recognised as a major factor influencing the recruitment

dynamics of P. merguiensis and worthy of future study.

During the presentation of the national data sets several problems in the collection, analysis and interpretation of the data sets were discussed:

- need for simultaneous sampling of life history stages to define cohort linkages;

- because prawn catches are seasonal it is easy to find spurious correlations with other seasonal effects; for this reason correlations with environmental data can only be done across many years, not within years;

- time and magnitude of spawning is hard to measure because of different methods used (e.g. % maturity and population fecundity index). Further, spawning stock size is influenced by the fishing pressure which affects seasonal patterns;

- data which defies interpretation should be considered suspect. Interrogate the data further and look for factors that would cause the gathering of aliased data (e.g. seasonal changes of catchability, fishing effort etc);

- taxonomic problems, especially of early life history stages (e.g. larvae and postlarvae), influence the resolution of abundance indices;

- in trying to follow the progression from one life history stage to the next it is dangerous to link peaks represented usually by only one point, especially with only 1 to 2 years of noisy data. One should adopt a broad-brush approach and look at windows (abundance over several months) of recruitment;

- combining survey data and commercial catch data, especially when a variety of gears and methods have been used, adds additional problems in interpretation. Size frequency information from the various gear types will aid in interpretation of the seasonal patterns;

- survey data provides a much more reliable index of abundance than the CPUE obtained from the fishery which is also influenced by many other factors, including changes in fishermen's behaviour;

- talk to fishermen to get facts but not explanations;

- amount of rainfall is not necessarily proportional to river outflow. River run-off and coastal hydrology will be differently affected by catchment size, drainage patterns, rain on remote inland areas etc.

3.3 DIRECT INDICES OF RECRUITMENT

For fisheries management, the recruitment index which we are most commonly interested in is the measure of the number of recruits to the fishery. No one is ever in a situation to actually count the number so instead scientists rely on a proxy. The index can be measured directly in some cases by using the CPUE of the recruitment phase or, in special cases, catch in weight.

CPUE of recruitment phase

Some index of abundance of the cohort during its recruitment phase could be used as an annual recruitment index. It will probably be proportional to the number which recruited if:

(a) the recruitment phase is of short duration
(b) it is unaffected by fishing

It should be remembered that CPUE may decrease if effort is large. Any changes in the fishing pattern may have an effect on the index, even though recruitment was constant.

Catch in weight

Catch (in weight) should be a reasonable estimator of recruitment if the yield per recruit (Y/R) remains constant. This should be the case if the fishing mortality (F) remains constant, and the size at first capture (L_c) remains constant or, alternatively when F is much greater than the natural mortality (M). It is extremely dangerous to use catch in numbers as an index of recruitment as it is very sensitive to changes in L_c even when F>>M. It must be remembered that:

$$C = R_o e^{-Mt_c} (F/Z)[1-e^{-Z(t-t_c)}]$$

where C = catch, R_o = recruitment, Z = total mortality, F and M are as defined above.

When R_o is obtained by dividing C in numbers by the exploitation rate $(F/Z)(1-e^{-Z(t-t_c)})$, an unnoticed change in the time of recruitment (t_c) will result in a significant error in the estimate.

This is not as significant when catch is measured in weight, because a change brought about by natural mortality will be compensated to some degree by an increase in growth of the individuals.

3.4 INDIRECT INDICES OF RECRUITMENT

When the above assumptions or conditions cannot be met (e.g. effort changes dramatically over time, the CPUE at the critical time is either unavailable or is affected by the fishing pattern itself) indirect indices should be used.

Catch / YPR

Dividing catch by yield per recruit will obviously give an estimate of recruitment. The problem however, is obtaining estimates of yield per recruit. It may be possible to obtain the yield per recruit in one year only, in which case the yield per recruit for other years can be estimated by estimating the fishing mortality (F) using F = qf, where q = the catchability coefficient, and f is the fishing effort. This assumes q is constant from year to year and, just as importantly, the pattern of F has also remained constant even though its absolute level has changed.

Pope's age-based cohort analysis

If the pattern of fishing effort has changed it is not a simple problem to calculate YPR from a comparison of annual effort. In the case where the year class in question recruits over a fairly small time range (say 4 months) and the fishery declines to relatively uneconomic level before the advent of the new year class, then it is possible to calculate a recruitment index for the population by using the back-calculation of an age-based cohort analysis.

For any age class (e.g. a month class), the number at the start of the period (N_1) is given by:

$$N_1 = N_2 e^{M} + C_1 e^{M/2}$$

where N_2 is the population at the start of period 2 and the other terms are as defined above.

This is an approximation in that all the catch is assumed to have been taken instantaneously at the midpoint of the time interval. The error is not severe and it simplifies the calculation of the recruitment index.

The expression can be extended so that each N is expressed in terms of the catch during the next interval, the natural mortality rate and number remaining at the end of the interval. The expression becomes:

$$R = C_1 e^{M/2} + C_2 e^{3M/2} + C_3 e^{5M/2} + \ldots + C_t e^{(t-.5)M} + N_{rem} e^{(t-1)M}$$

with a value of M and "terminal F", N_{rem} can be estimated and consequently recruitment, R. It can be shown that as long as F>M, the choice of terminal F is relatively unimportant.

Length based cohort analysis

Catch-at-length data differ from catch-at-age data in that they do not pertain to a given cohort as described above. VPA, however, can be run on catch-at-length data using a modified cohort analysis technique. The first of these is not intended to reconstruct any given cohort but rather to reconstruct an average cohort using catch data covering the life span of several cohorts. The results of this type of analysis are population sizes and fishing mortalities related only to size but not time. These results cannot be used to manage fisheries in

real time or to study temporal fluctuations in recruitment. The second technique is to assume that all prawns in the population have the same growth parameters and derive a length based VPA.

As above, the number (N_t) at the start of a time period Δt is given by:

$$N_t = N_{t+\Delta t}\ e^{M\Delta t} + C_t\ e^{M\Delta t/2}$$

The deterministic growth rate can be described by the von Bertalanffy growth equation in the form:

$$L_t = L_\infty (1 - e^{-K(t-t_0)})$$

where L_t is the length at time t, L_∞ is asymptotic length, K is the growth coefficient and t_0 is the hypothetical age when the prawn would have been zero length

so that

$$t = t_0 - 1/K \ln (1 - L/L_\infty)$$

It follows that a prawn of length L_1 should have an average age given by

$$t_1 = t_0 - 1/K \ln (1- L_1/L_\infty)$$

and a prawn of length L_2 should have an average age of

$$t_2 = t_0 - 1/K \ln (1 - L_2/L_\infty)\ .$$

Substituting in the original formulae gives:

$$N_t = N_{t+\Delta t}\ ((L_\infty - L_1)/(L_\infty - L_2))^{M/K} + C_{t+\Delta t}\ ((L_\infty - L_1)/(L_\infty - L_2))^{M/2K}$$

Having determined the value of N_L for the largest prawn, successive applications of the equation should lead to estimates of N_L for smaller prawns. The rate of exploitation (F/Z) for each length group can then be determined from the relationship.

$$F/Z = (\text{number caught/number dying})$$

Several packages are available to carry out length-based cohort analyses for prawns. The two most commonly used packages are ELEFAN (ICLARM) and LFSA (FAO). Both packages have similar objectives and in terms of their VPA components are essentially identical. The main difference is in the method used for estimating the growth parameters K and L_∞ for input into the VPA. LFSA uses Bhattacharya's method to estimate the mean size and variance of the component age groups in a sample and then link these estimates using modal progression to get growth parameters. ELEFAN, in contrast, estimates the parameters from the best fit to a series of length frequency samples (usually taken over one year). The complete ELEFAN now contains an interactive Bhattacharya's method for comparison. LFSA provides an utility to

reformat the data so that either package can be used on the same data.

3.5 INTER-ANNUAL VARIABILITY

As defined on the first day of the workshop, recruitment is a function of the initial egg production and survival of prawns up to a given life-history stage. On average, survival will be inversely related to the population size but can be extremely variable due to stochasticity of both biotic and abiotic mortality factors. Multiple regression analysis is one technique commonly used to examine the influence of the environment on recruitment. The technique, however, must be applied carefully to ensure correct interpretation of the results. The technique simply fits models of the form:

$$\text{Recruitment} = A + B1*\text{Factor1} + B2*\text{Factor2}.....$$

where A and B are parameters estimated from the data and Factor 1 and Factor 2 are the chosen variables to examine. A correlation matrix to examine the relationships among the variables themselves is important to the understanding of the overall analyses. The order in which the variables are entered into the relationship affects the relative influence of each variable. A step-wise regression technique, can be used to build models which include the more important variables in order of their apparent importance. Care must be taken to identify relevant variables based on known recruitment mechanisms and keep the number of factors to a minimum. The inclusion of too many factors will ultimately appear to explain all the variability in any data set.

The approach should be to identify recruitment mechanisms, obtain the necessary data and then test hypotheses using the regression analysis. An exploratory examination of the available variables, however, can be useful to identify factors which require further biological research. Insignificant results can mean that the wrong variables have been included (e.g. rainfall taken over the wrong period), the wrong model applied (e.g. linear model assumed), insufficient data spread over the variable of interest as well as a lack of accuracy in the estimation of either the recruitment or the environmental variable which will obviously confound the result. On the contrary an apparently good result could be produced by the leverage of only a few outlying data points.

3.6 STOCK RECRUITMENT MODELLING

In our studies on prawn fisheries, we are interested in the changes that occur in a prawn population over time as well as understanding the factors which cause those changes. These factors may be both biotic and abiotic and will include fishing activities. It is not possible to gain intricate knowledge on all the factors involved and what normally happens is that any modelling of the dynamics will simply lump together many of the factors as if they act as just one. The more factors that are lumped together, the greater will be the scatter in any statistical fitting of parameters and the less the precision will be in any predictive use of the models.

With banana prawns, we may be interested in:

(a) the number of spawning females
(b) the factors affecting larval survival
(c) the recruitment of postlarvae to nursery grounds
(d) the factors affecting juvenile survival
(e) the number of emigrants from the nursery grounds
(f) the factors affecting subadult survival
(g) the recruitment of subadults to the fishing grounds
(h) the factors affecting adult survivals
(i) the subsequent number of spawning females

In practice, items (b) through (f) can not be separated without an intensive research effort and are usually considered as one factor which determines the relationship between the mothers and the subsequent year's recruitment into the commercial fishery. This we will refer to as the **stock-recruitment** relationship. Because there are so many factors involved in determining this relationship, any attempt at simplifying its form will result in a large degree of variation in data.

Ricker states..."our knowledge of population regulatory mechanisms in nature is so slight that it is usually difficult to choose among different curves (models) on this basis, so we usually fit the simple curve (model) that looks most appropriate".

There are certain properties that such a model must have.

1. When there are no spawners, there will be no recruits (it must pass through the origin).

2. Recruitment should not be eliminated at high densities (it should never fall to zero at high levels of spawning). With prawns, one could argue that it should rise to an asymptote and never decrease, reflecting a set carrying capacity of the nursery areas.

3. Recruits per parent should decrease monotonically with increasing parental abundance.

4. Recruitment must exceed parent stock (in the same units) for levels lower than a certain point otherwise the stock will tend to extinction.

The two common models used are that of Ricker and that of Beverton and Holt.

$$R=aSe^{-bS} \qquad \text{.....Ricker}$$

$$R = 1/(a+b/S) \qquad \text{.....Beverton and Holt}$$

where

R = number of recruits
S = size of parent stock (in numbers, weight, egg production, etc)

a, b are parameters

The easiest way to estimate values a and b, is to use a non-linear regression program, as provided by many statistical packages such as SYSTAT on many PC's.

Because the R and S represent different generations, they are referred to as R_{t+1} and S_t.

We are most interested in knowing the impact of fishing on the long term recruitment to the fishery. Fishing affects the number of females that will survive to spawn for a given level of recruitment.

$$N_t = N_o e^{-Zt}$$

Now substitute $S_t = aN_t$, $R_t = bN_o$, $Zt = t(qf+M)$

and whereby

$$e^{-Zt} = e^{-Mt} e^{-qft}$$

where t is the time between recruitment and spawning and if we choose the units for t in terms of this duration then t = 1.

Hence we can reduce this to a form of

$$S_t = cR_t e^{-df_r}$$

where c and d are constants, S_t is the spawning index, R_t is the recruitment index, and f_r is the fishing effort during the period between recruitment and spawning.

4. EXAMINATION OF RECRUITMENT PROCESSES

4.1 LARVAE

Analyses of the seasonal dynamics of Penaeus merguiensis in many regions showed that periods of high spawning intensity do not necessarily result in high abundance of postlarvae in the nursery areas. Research has been carried out in the south-eastern Gulf of Carpentaria in Australia in an attempt to explain these anomalies. Sampling of larvae at different depth zones has been used to describe the vertical migratory behaviour of all the different stages of larvae. In conjunction with computer models on the current speeds and direction in the Gulf it has been possible to demonstrate that offshore advection of larvae occurs during the main period of egg production and few larvae reach the coast. In contrast, onshore advection occurs during the period of low egg production and the large influx of postlarvae results in the generation which supports the commercial fishery.

4.2 POSTLARVAE

Research on factors affecting the recruitment of postlarvae into the nursery areas has also been carried out for Penaeus merguiensis in the

southern Gulf of Carpentaria. As postlarvae approach the coast, their vertical migratory behaviour becomes more under the influence of tidal rather than diurnal rhythms. The postlarvae move up in the water column at low slack water and are carried towards the estuary on the flood tide and settle back down to the bottom at high tide. This presumably prevents the postlarvae from being washed back out to sea. Other species and genera react to both tidal and light cycles. More P. merguiensis postlarvae enter the estuary during the spring tide period with an extra large peak on alternate spring tides.

4.3 JUVENILE MORTALITY AND EMIGRATION

After entering the estuary, postlarval P. merguiensis from the main effective spawning season settle out in the tidal creeks of the mangrove estuaries. Mortality during this stage is extremely high, mainly as a result of fish predation. Studies on the mortality and growth of juvenile prawns in the laboratory have shown that survival is highest at low temperatures (20°C) although growth is highest at 30°C. After 2 or 3 months in the estuary, the juvenile prawns begin to emigrate back out into the inshore region. Sampling in different depth zones has shown that the main migration pathway is close to the water surface. Many factors are known to stimulate this migration. As with the immigration of postlarvae, more prawns move during the spring tide, especially every alternate spring tide. In the southern Gulf of Carpentaria, rainfall has a large influence on the number and size of emigrating prawns. This influence in turn, results in large catches in years of high rainfall and low catches in other years when rainfall is low.

4.4 PREDATION

Predation can be a very important factor of mortality and of year to year variations in recruitment. A study of fish predation on commercial penaeid prawns is being carried out in the eastern Gulf of Carpentaria. Adult prawns at the Albatross Bay study site are consumed in very significant quantities by a wide array of fish including: Caranx bucculentus, Carcharhinus dussumieri, Himantura toshi, Johnieops vogleri and Rachycentron canadus. The species of penaeids consumed varies seasonally and on a diel basis. Biomass estimates of fishes together with dietary data indicate that fishes consume considerably more prawns in Albatross Bay than are caught by fishermen. Juvenile prawns in the Embley estuary study area are also heavily preyed upon by many fishes, including: Scomberoides commersonianus, Lates calcarifer, Himantura uarnak, Polydactylus sheridani and Carcharhinus spp. Work is continuing offshore and in the estuary, both to increase the accuracy of seasonal dietary information and to refine fish biomass estimates, hence leading to accurate assessments of quantities of penaeids consumed. It is essential that comparative work is undertaken as soon as possible in order to test the general applicability of the results obtained so far.

5. DISCUSSION OF SAMPLING TECHNIQUES

5.1 ESTIMATION OF REPRODUCTIVE OUTPUT - SPAWNING INDICES

The estimation of an appropriate index of spawning activity which can be used to describe seasonal and spatial spawning problems can be discussed in three stages:

(i) definition of spawning individuals;
(ii) estimation of an appropriate index of reproductive output; and,
(iii) the identification of critical spawning pattern in the life history.

Visual and histological methods can be used to identify spawners. An appropriate definition of a spawner is the histologically derived measure of ripe (ready to spawn) and spent ovary stages combined. Knowledge of the temporal aspects of the spawning cycle has provided an estimate of time to spawning when using ovary stages 4 and 5 as the indicator of spawning.

This commonly used "percent maturity" index (often ovary stages 3 and 4 or just 4) does not provide an appropriate index of spawning activity. A better estimate of reproductive output is an index of population fecundity, accounting for the proportion of spawners, population abundance, and fecundity. Data from several studies demonstrated that each of these factors can have a dramatic effect on the estimate of reproductive output.

Critical spawning periods in the life history do not necessarily coincide with spawning periods or locations of greatest magnitude of reproductive output, especially on heavily exploited stocks. Data on seasonal recruitment to each life history phase following spawning indicated the need to consider subsequent life history phases in order to define the critical spawning periods defined as the periods when the bulk of the stock is being generated.

5.2 LARVAL SAMPLING AND IDENTIFICATION

The sampling strategy for larvae is affected by the extremely low relative abundance of penaeid larvae in respect to general plankton biomass and their very small size. Therefore, nets sampling early larval stages (protozea) must have a fine mesh (125-250 microns) depending on species and very large filtering to mouth area ratio (ca. 10:1) to prevent clogging in turbid coastal waters. Plankton tows should be stepped oblique from near the bottom to the surface to take into account the diurnal vertical migratory behaviour of the larvae.

Larval identification of the species level can only be effected by the use of numerical taxonomic techniques. This is possible only if the species of known identity are in a reference collection. Workshop delegates were advised that to extend the techniques developed at CSIRO to the suites of species in their study sites, more work (larval rearing, numerical taxonomy) would have to be done throughout the network.

5.3 CATCHABILITY

Catch of penaeids can vary very widely even over short time periods at the same site and with the same gear. These changes are largely due to the behaviour of prawns. This behaviour can be influenced by several factors including light (day or moon), tide, temperature, turbidity and moult condition. Species which bury such as P. semisulcatus and M. ensis, tend to be less catchable during the day or in bright moonlight - other species such as P. merguiensis may avoid capture by swimming up into the water column. This behaviour appears to be affected both by light and by tides. Different types of gear have different capabilities of catching different species or sizes. Mesh size of net influences size composition and so it is important to standardize on gear when carrying out long term sampling and to take mesh size and gear into account when comparing survey and commercial catches.

Sampling programmes need to take into account these variations as described below in considering general sampling strategies.

5.4 TAGGING

The most satisfactory tag for penaeids is the streamer tag which can be obtained in a range of sizes to suit different sizes of prawns. It is inserted by means of a needle and should be positioned through the joint between the first and second abdominal segments; other positions result in lower survival. The behaviour of prawns changes for several hours after tagging; P. semisulcatus for example doesn't bury for several hours even in daylight; P. merguiensis tends to swim up to the surface even during the day. Newly tagged prawns released at the end of the night or in the day have a lower survival than those released early in the night. Newly tagged prawns should not be released at the surface because they will have a high probability of being eaten by predators. Cages which release the prawns on the bottom, should be used.

The size of prawns used for tagging is critical for two reasons. Prawns smaller than 12-15mm carapace length have a reduced probability of surviving the trauma of being caught, handled and tagged and this should be taken as the lower size limit. A second problem is that natural mortality of small prawns is higher than that of the larger sizes. Consequently, fewer returns will be obtained from small than from larger prawns.

A tagging programme has to have an effective system for recovering tagged prawns. This requires extensive advertising of tagging and, ideally, a reward system. Fishermen should be encouraged to return tagged prawns, not merely the tags. The position-finding ability of fishermen needs to be taken into account in deciding the site of recapture. Tag returns within the first 30 days of release give little information on growth or movement.

5.5 SAMPLING STRATEGIES - GENERAL

All life cycle stages show large variability in abundance at

various time scales. In order to identify the seasonal patterns care must be taken to consider carefully the existence of diel, tidal and lunar cycles and to adopt appropriate sampling strategies to filter their effects. A common approach is to sample intensively for a year, at high frequency to identify these cycles and then set the long term sampling programme at the appropriate time (i.e. usually when expected catches are the highest).

This process could, however, be expensive and a way to reduce costs and time involved would be to:

(i) Search the literature and fishermen's knowledge for a possible catchability model for the life stage under investigation (diel or tidal cycles etc.);
(ii) Test this model using intensive sampling over (2 or 3 days, and several tidal cycles);
(iii) If the results conform to the model, start sampling using an appropriate strategy to reduce the variability of the "average" abundance over longer time periods, such as weeks or months.
(iv) To ensure that the model is not drifting with time (e.g. subject to seasonal changes etc.), the original model should be tested regularly.

After a full seasonal cycle of regular sampling and testing, one should not assume that one has all the information needed. Some ad hoc testing should be applied to test for more changes (hurricanes or very bad weather for instance).

A similar sampling problem exists with spatial variability and a similar approach could be defined (e.g. get model from literature and fishermen's knowledge, test it, set sampling sites, but include additional samples to test original assumptions). Systematic sampling on a grid square basis usually provides better results than random sampling. When a gradient exists such as decreasing numbers of animals with distance from the coast, samples should be taken along the gradient (i.e. perpendicular not parallel to the coast).

6. FUTURE PREP ACTIVITIES

6.1 PREP REGIONAL NETWORK

All participants at the workshop agreed that the concept of a regional network of prawn researchers throughout the region would help to enhance the collection and analyses of data and provide a common background for the interpretation and implementation of results. Through a regional network of teams at the national level, important management questions concerning the risk of recruitment failure for different species could be addressed. The aim of the network was to provide for communication, common methodology and facilities and additional resources for already ongoing research. It was noted that the project was not starting from scratch and that some level of research was already taking place in each participating country (see attached National reports).

To make the network effective it was recommended that PREP should be restricted to a few (generally 2) penaeid prawn species in one or two study sites within each country. Research at a national level, should of course, proceed on other species according to national priorities. The three major species considered most important for future PREP activities by the majority of countries were Penaeus merguiensis, P. semisulcatus and Metapenaeus ensis.

6.2 NATIONAL REQUIREMENTS (see also Chapter 7)

On the basis of the wide range of recruitment related topics presented at the workshop, participants were asked to outline the type of research they planned to carry out in the future and what was needed to facilitate their research. Four of the six countries recognised the need to collect better information on early life history stages, including sampling on larvae, postlarvae and juveniles. Of those countries already collecting this type of information, a major emphasis was put on reviewing existing data and data collection systems with a view to improving data quality. The need for better environmental data, especially coastal oceanographic information was noted. Most countries recognised the need for further training in sampling techniques and sampling design, taxonomy, especially for larval and postlarval stages, data analyses and use of computer packages. Computer equipment and software was required by several countries to facilitate data analyses.

It was recommended that recruitment research should follow three major phases. Although the phases are not necessarily sequential they provide the basis for organizing future research plans. The phases involve:

(i) Description (description of life history dynamics etc.)
(ii) Correlation (examination of potential causal factors, both biotic and abiotic, affecting recruitment)
(iii) Mechanisms and processes (examination of the causal mechanisms affecting recruitment variability)

6.3 PREP IMPLEMENTATION

PREP is considered to be the catalyst for the development of a regional network of researchers and institutions involved in prawn recruitment related studies and will seek to provide the medium/long term infrastructure of both funding and technical support to enable collaborative research through the Indo-West Pacific region.

To support PREP's projected activities over an initial 3 year period the workshop recommended that support be sought from UNDP to provide core funding to enable national efforts in training, research and communication to be coordinated at the regional level.

It was agreed that annual workshops addressing issues such as sampling techniques, data acquisition, storage and analyses should provide the base level training required for a regional cooperative

research effort and the opportunity to regularly evaluate project progress. The annual meeting would also provide the forum for country coordinators and technical and administration coordinators to plan the direction of the project.

The following timetable was drafted on the assumption that the submission seeking UNDP support, if successful, would enable the project to commence in early 1989.

Commencement Date : February 1989.

Year 1	- Collection of seasonal data on different life history stages; - Increase quality of monitoring of commercial catch data for specific study sites; - Evaluation of national requirements (equipment and training) to support lowest common denominator level participation;
July/August	- Methodology workshop on sampling techniques, sampling designs, data acquisition and storage; - National coordinators/technical coordinators project management meeting (to coincide); - Equipment purchase and ad hoc training as required.
Year 2	- Data acquisition and storage (cont.); - Equipment purchase/ad hoc training (cont.);
July/August	- Workshop on data compilation and analysis emphasizing correlation analysis; - Management meeting (to coincide); - Commence analysing processes.
Year 3	- Data acquisition and storage (cont.); - Scientific seminar - geographic comparisons; - Training in recruitment modelling; - Analysis of factors affecting recruitment;
July/August	- Final workshop and report (including recommendations for future research and for management).

The workshop recognised that if the funding submission was unsuccessful, a delay in full scale implementation would occur until an alternative sponsor could be found. It was agreed, nevertheless, that a further workshop should be convened towards the middle of 1989 to evaluate national progress resulting from the present workshop.

To co-ordinate the various activities within the network, it was recognised that both technical co-ordination and administrative management was required. Technical co-ordination, in the first instance will be provided by Dr. P. ROTHLISBERG in his capacity as Technical Programme Co-ordinator for WESTPAC/OSLR and Dr. D. STAPLES, Project Leader for PREP. The Project Leader will be responsible for the overall co-ordination of research and communication within the network while the administrative management will provide a focal point for the financial

responsibility for the purchase of equipment and supplies, the organization and co-ordinations of workshops and meetings as well as the preparation and distribution of publications. It is obvious that close co-ordination between the scientific and administrative management of the network will greatly enhance its chances of success and for this reason it was recommended that both be based within the region.

7. GENERAL RECOMMENDATIONS

7.1 SCIENTIFIC APPROACH

The workshop recommended the adoption of a common research approach based on the following scientific objectives:

(a) Collect seasonal data on all life history stages of the prawns and describe average seasonal patterns of abundance of the states (and anomalies).
(b) Define the life cycle timing and reproductive strategies for the species by linking the seasonal patterns of the different life history stages and establish the critical time/space windows for quantifying recruitment indices for the main cohorts in the populations.
(c) Establish inter-annual correlations between selected environmental and biological variables and appropriate recruitment indices.
(d) Identify causal mechanisms underlying any significant correlations, including effects of climate, ocean and estuarine processes, habitat and predation.
(e) Develop environmental stock recruitment models for predicting changes in recruitment brought about by changes in both fishing pressure and other environmental/biological factors.

The workshop also recommended concentration on a few selected species : Penaeus merguiensis will be common to all study sites - one or two other important species will be studied at each site (chosen on the basis of their local importance.)

The workshop further recommended concentration on a few selected sites to increase research efficiency with the means available.

7.2 FINANCIAL SUPPORT

The workshop agreed that the UNDP project document is relevant to the needs of the participating countries. It agreed in particular with the Network approach. The workshop recommended that the project document be presented immediately by FAO (who has already submitted a preliminary version of the document) and IOC to UNDP for funding.

The participants agreed to support the project at the national level and seek support through their own authorities, as well as, other national and bilateral funding agencies. If UNDP does not support the project it should be presented to other donors.

7.3 PROJECT MANAGEMENT

Considering the need for real time interaction in a project of this nature, and recognizing that close relationships between country coordinators, technical coordinator and project management is the essence of a successful network, the workshop recommended that the management of UNDP funds made available in support of PREP be based in the region.

The draft UNDP submission reflects this recommendation and on that basis the CSIRO Institute of Natural Resources and Environment (Australia) has indicated a willingness to provide the project management staff required as an element of its support for PREP.

In addition to providing project management support as identified under Item 6.3 it would also be expected that the project manager, in consultation with technical supervisor and country coordinator, would also:

(a) identify other opportunities e.g. UNESCO, ICLARM, SEAFDEC etc, computer training courses, which could supplement PREP efforts;
(b) establish closer relations with various development assistance projects of relevance, e.g. USAID ASEAN-Australia Coastal Resources projects with a view to data sharing, etc;
(c) schedule annual workshops to coincide with other meetings, e.g. ASEAN meetings, so as to maximize efficient use of funds.

7.4 FUTURE ACTIVITIES

National level

It was agreed by the participants that they should develop/strengthen their research programmes following the guidelines discussed during the workshop. They should also bring to the attention of their agency directors, their relevant research agencies and national funding bodies, the existence of PREP. At this time they should identify the national needs for support.

Network level

It was agreed that information flow throughout the regional network would be strengthened by communication on a global network (e.g. Network of Tropical Fisheries Scientists). A new workshop is recommended within a year, on methodology, data collection and acquisition.

TABLE 1 - Summary of National Study Sites

Country	Site	% *Penaeus merguiensis*	Main species	Estuary	Inshore <20m	Offshore >20m	Catch (avg)
AUSTRALIA	Albatross Bay 1300km^2	Trawl 70%	*Penaeus merguiensis*	-	-	Trawl	800 t
INDONESIA	Cilacap 3000km^2	Trawl 15% Trammel 30%	*Metapenaeus ensis*	Trap	Trammel Beach seine	Trammel Trawl (<1980)	Trawl 600 t Trammel 200 t Beach seine 30 t Trap 860t
MALAYSIA	Larut Matang 1500km^2	Trawl 5% Trammel 76% Push 74%	*P. merguiensis*	Push net	Trammel	Trawl	Trawl 32 t Trammel 235 t Push 69 t
PAPUA NEW GUINEA	Gulf of Papua 9750km^2	Trawl 54%	*P. merguiensis*	Beach seining Scoop nets	Trawl > 3miles	Trawl	Trawl 570 t Seine - Scoop -
PHILIPPINES	Sorsogon Bay 120km^2	<1%	*Metapenaeus* *Trachypenaeus*		Mini-Trawl Gill nets Corrals		11 t 3 t 4 t
THAILAND	Bandon Bay 20000km^2	Trawl 2% Trammel 70%	*Trachypenaeus* *Metapenaeopsis* *Parapenaeopsis*	Set bag net	Push net	Trammel net trawl	Trammel & trawl 2000 t Push net 300 t Set bag net

Data needed: 1. sizes caught 2. fishery areas covered

Table 2 - Available data on seasonal (monthly summaries) pattern of life history stages of Penaeus merguiensis, rainfall, temperature and fishing effort.Number in parenthesis is years of data. S = research survey: C = commercial fishery

	Australia	Indonesia	Papua New Guinea	Malaysia	Philippines	Thailand
Spawners						
% maturity	S(3)	S(8)	-	-	S(2)	S & C(1)
Pop. fecundity	S(3)	-	-	-	-	-
Larvae						
early (p)	S No./m^2 (3)	-	-	-	-	-
late (m)	S No,.m^2 (3)	S. No./hr (1)	-	-	-	S No./m^3 S (1)
Postlarvae (P)	-	S No./hr (1)	-	-	-	S No/m^3 (1)
Postlarvae (B)	S No./m^2 (2)		-	-	-	S No./m^3 (1)
Juvenile	S No./m^2 (2)	S kg/month (1)	-	C kg/boat/d (7)		S g/hr (1)
Emigrants	S No./ebb tide (2)	C kg/month (1)	-	C kg/boat/d (7)	-	-
Subadults	S No./Std trawl (3)	C kg/month (14)	-	C kg/boat/d (7)	-	S/hr (1)
Adults	kg/boat-day (18)	(11)	C kg/hr (10)	C kg/boat/d (7)	S kg/boat (2)	S g/hr (1)
Rainfall	>1970	>1972	>1976	>1970	>1973	>1970
Temperature	>1970	>1980	Water >1977	>1970	>1970	>1970
Fishing Effort	trawl	trawl trammel	trawl	trawl (7) trammel (7) seine (7)	Mini-trawl	trawl (<18m)
	No. of boat days	No. of boat days	No. of boat days	No. of boats	No. of boat days	hour

Table 3 - Summary of seasonal timing of various life history stages of Peneaus merguiensis and rainfall. Numbers indicate month of the year of peaks or windows of high abundance. 1° = primary (larger) peak, 2° = secondary (smaller) peak.

	Australia	Indonesia	Malaysia	Papua New Guinea	Philippines	Thailand
Spawning						
% mature	9 - 11	1° 3,4,5 2° 8 - 11	-	-	1° 7 - 9 2° 1,2	1° 9 - 11 2° 3 - 5
population fecundity	2,3	-	-	-	-	
Larvae						
early (p)	2,3	-	-	-	-	
late (m)	-	?*	-	-	-	1° 2,3 2° 8,9
Postlarvae	1° 10,11 2° 2,4	12,1	-	-	-	9
Juveniles	1° 11,12 2° 3,4	12,1	8,10	-	-	5,7
Emigrants	1,2	-	1,5	-	-	-
Subadult	-	-	2,4	-	12	8 -11
Adult	2,3	9 - 12	1° 3 - 6 2° 10 1 - 12 **	1° 4 - 7 2° 11-1	10 - 1	9 - 11
Rain	12 - 2	1° 10 - 1 2° 3 - 6	1° 10,12 2° 3,4	5 - 7	1° 10-1 2° 7	10,11

* mixed spp across family Penaeidae

** drift and trammel nets

*** mini-trawler, unreliable effort data

ANNEX I

LIST OF ACRONYMS

CORDERP - Coral Reef Demersal Recruitment Project (TRODERP)

FAO - Food and Agricultural Organization of the United Nations

FEDERP - Fish Estuarine Deltaic Recruitment (TRODERP)

IOC - Intergovernmental Oceanographic Commission

IOCARIBE - IOC Sub-Commission for the Caribbean and Adjacent Regions

IPFC - Indo-Pacific Fisheries Commission (FAO)

IREP - International Recruitment Programmme (OSLR)

OSLR - Ocean Science in Relation to Living Resources (IOC/FAO)

PREP - Penaeid Recruitment Project (WESTPAC, IOCARIBE)

RT - Red Tide Project (WESTPAC)

SARP - Sardine/Anchovy Recruitment Project (IREP/OSLR)

SCORRAD - Standing Committee on Resources Research and Development (FAO/IPFC)

TRODERP - Tropical Demersal Recruitment Project (IOCARIBE/OSLR)

WESTPAC - IOC Regional Committee for the Western Pacific

ANNEX II

ABBREVIATED HISTORY OF PREP

September 1983 - WESTPAC III, Townsville, established OSLR component of WESTPAC (Tranter)

July 1984 - IOC-FAO/OSLR-GGE-I, Paris, proposed WESTPAC-OSLR on penaeid recruitment

October 1984 - FAO-Australian Workshop on Penaeid Management, Kooralbyn, held informal discussions

March 1985 - Thirteenth Session of IOC Assembly, Paris, endorses IREP initiatives

February 1986 - WESTPAC/AMSA, Hobart, Lasker-penaeid recruitment-ENSO

April 1986 - Tranter proposal to IOC, Penaeus merguiensis recruitment

April 1986 - IOC/FAO TRODERP Workshop, Ciudad del Carmen, Mexico adopted regional/comparative approach

May 1986 - Asian Fisheries Forum, Manila, Staples/SE Asian study tour

December 1986 - IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence, Townsville, Australia (IOC Workshop Report n°47)

February 1987 - IPFC-SCORRAD Meeting, Darwin, adopted Preliminary PREP Proposal

June 1987 - IOC-FAO/OSLR-GGE-II, Rome WESTPAC PREP tabled and endorsed
- UNDP proposal drafted
- WESTPAC Expert Consultations, Bangkok
- WESTPAC IV, Bangkok, PREP tabled and endorsed

January 1988 - IOC/FAO (WESTPAC/SCORRAD) PREP Mission to region

March 1988 - XXI Session of the IOC Executive Council endorsed WESTPAC
- IV Report endorsed

July 1988 - IOC/FAO PREP Workshop, Cleveland

ANNEX III

AGENDA

Sunday 24 July

- Welcoming Reception : CSIRO Marine Laboratories, Cleveland

Monday 25 July

Introduction
Harriss, Rothlisberg, Staples, Garcia

- Welcome
- Introduction to PREP, IOC, FAO
- Structure and objectives of workshop

Descriptions of study sites and fisheries

- Description of national study sites and fishery characteristics
- Preparation of catch and effort data and trend analyses

Seasonal patterns
Staples

- Seasonality in the abundance of different life history stages
- Seasonality of rainfall and temperature
- Seasonality of fishing

Tuesday 26 July

Life history dynamics
Staples

- Presentation of national results
- Interpretation of results

Direct recruitment indices
Staples, Somers

- Critical periods for spawning and recruitment
- Selection of larval, postlarval, juvenile and adult recruitment indices
- Between cohort comparisons
- Geographic comparisons

Wednesday 27 July

Indirect recruitment indices
Garcia, Somers

- Indirect methods for estimating recruitment indices
  (i) LFSA (ii) ELEFAN (iii) BEAM1

Interannual variability/effect of environment
Staples, Somers
- Introduction to statistics package
- Environmental/habitat correlations: Stepwise regressions
- Analyses of national data sets and geographic comparisons

Thursday 28 July

Effect of fishing
Garcia, Somers

- Stock:recruitment:environmental modelling
- Multi-stage modelling
- Analyses of national data sets and geographic comparisons

Recruitment mechanisms
Rothlisberg, Staples, Blaber

- Larvae
  Advection of larvae, larval mortality
  recruitment of postlarvae to nursery areas
- Postlarvae and juveniles
  Settlement, survival of juveniles (include habitat and predation), emigration from nursery areas
- Sub-adults and adults
  Inshore predation and recruitment to fishery

Sampling techniques
Staples, Crocos, Rothlisberg, Hill

- Egg production indices
- Larval sampling and identification
- Catchability and behaviour of juveniles and adults
- Sampling design

Friday 29 July

Future data needs

Garcia

- Discussion of data requirements (Biotic and abiotic)
- Data summaries from Workshop
- Standardisation of methods (including data storage)
- National research plans

Saturday 30 July

Future Activities of PREP

Garcia, Rothlisberg, Staples

- Regional Coordination/Implementation/Funding
- Preparation of Workshop reports including National appendices

- Workshop Dinner

ANNEX IV

NATIONAL RESEARCH REPORT FORMAT

INTRODUCTION:

- Selection of study site
- Other national/international research at site

DESCRIPTION OF STUDY AREA:

- Map (area)
- Habitat
- Fisheries

TRENDS IN CATCH AND EFFORT:

- Graph
- History of fishery and data collection
- Effort definition (units of measure)

SEASONAL PATTERNS:

- Life history stage - graph
- Environmental factors
- Fishery

SELECTION OF RECRUITMENT INDICES:

- Interannual variability of stock/environment

ANNEX V

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ANNEX VI

STUDY SITES OF NATIONAL REPORTS

Australia	Study sites: Albatross Bay Queensland east coast
Indonesia	Study site: Cilicap
Malaysia	Study site: Larut-Matang
Papua New Guinea	Study sites: Gulf of Papua Daru
Philippines	Study site: Sorsogon Bay
Thailand	Study site: Ban Don Bay

ANNEX VII

NATIONAL RESEARCH REPORT

AUSTRALIA

ALBATROSS BAY

1. INTRODUCTION

The Albatross Bay study site supports populations of all of the main commercial species of penaeid prawns in the Gulf of Carpentaria, and also provides a wide range of juvenile habitat types contained in a relatively small area. The distribution of adults is fairly discrete, enabling the study of an entire population. Data from previous projects in this area have provided information on habitat preferences for the main commercial species, and basic life history patterns for both adult and juvenile phases. This information has provided preliminary data for, and to some degree identified, some of the basic questions for the study of recruitment processes.

2. DESCRIPTION OF STUDY AREA

2.1 Study Area. Albatross Bay in the north-eastern Gulf of Carpentaria is a relatively shallow (up to 20m depth), soft bottomed open embayment of approx. 1300 km^2 adjacent to three estuarine systems which extend up to 60 km inland (Figs. 1 and 2). These estuaries provide extensive mangrove and seagrass habitats.

2.2 The Fishery. Penaeus merguiensis constitutes the major part of the commercial catch, with P. semisulcatus and M. ensis constituting a minor component. Penaeus merguiensis provides 70% of the scientific survey catch. The fishery is subject to a management imposed seasonal closure, limited entry, and gear restrictions common to the Declared Northern Prawn Fishery Management Zone in Northern Australia. The fishery is subject to intense fishing effort following the opening of the fishing season each year. The high exploitation rate results in a short fishing season of several weeks duration.

3. TRENDS IN CATCH/EFFORT

Commercial catches were first taken at Weipa in the late 1960's at a low level of fishing effort. After two years of high catches in 1971 and 1972 (nearly 2000 tonnes), catches dropped sharply in 1973 to 600 tonnes. Since then there has been no marked trend in catches although they have fluctuated from year to year (Fig. 3a).

Between 1970 and 1983, fishing effort has fluctuated about a high level but since 1983 there have been some years of relatively low effort (Fig. 3b) notably 1984 and 1986. Although total annual fishing effort has not changed dramatically through most of the life of the fishery, the time over which that effort has been expended each year has

gradually decreased. In 1968, commercial catches were taken from February through to October but in recent years the majority of the total catch has been taken in the first 2 to 3 weeks of the fishing season.

Since the early 1970's, a seasonal closure has been in force. In recent years the closure has been from January 1st to April 15th each year allowing prawns to grow to a larger and therefore, more valuable size.

Fishing effort is defined as the number of boat days spent either fishing or searching for banana prawns. Catch and effort by species and area fished are recorded in fishermen's log books but the log books do not provide 100% coverage of the fishery. Log book data is combined with landing weights provided by processors to provide estimated total catch and effort data.

4. SEASONAL PATTERNS

In general, the study area is marked by strong seasonality in environmental variables and in all life-history stages.

Adults are most abundant in January to March but numbers decrease sharply due to the effect of the intense commercial fishery (Fig. 4d). Egg production and levels of offshore larvae are highest in February-March (Fig. 4a). These peaks appear to result in postlarvae and juveniles in the estuary from April to May. These juveniles, however, do not emigrate into the offshore fishery at this time (Fig. 4c), but appear to over-winter in the estuary, where numbers gradually decrease due to natural mortality.

A relatively low level of adults in the offshore area in September to November has a high percentage (%) of ripe females and this spawning gives rise to substantial numbers of postlarvae and juveniles in the river from October to December. The major emigration of this generation occurs from November to February and appears to be in response to the seasonal peak of rainfall (Fig. 5). Subadults recruit to the offshore region from January to March (Fig. 4d).

In summary, it seems that egg production, larvae and juveniles from the peak of spawning in the large adult populations in February/March contribute virtually nothing to next years commercial catch while spawning in the relatively small adult population in September/October produces the majority of next season's catch.

5. SELECTION OF RECRUITMENT INDICES

Although effort shows some variation from year to year it is always high enough to catch a high proportion of the available population i.e. the fishery is highly exploited. Therefore, for the Weipa banana prawn fishery, total catch by weight is the best estimate of P. merguiensis recruitment. Spawning indices were taken as the CPUE for P. merguiensis during the months from September to November.

6. INTERANNUAL VARIABILITY

There is no strong correlation of annual rainfall or summer rainfall with adult catch (in contrast to south-eastern Gulf and despite observation that emigration of large juveniles occurs during the wet season).

The reason may be that interannual variability in rainfall is not as great as in south-eastern Gulf and average level of rainfall is approximately twice that of south-eastern Gulf.

The hypothesis then, is that there is always enough summer rainfall at Weipa to cause emigration of large numbers of juveniles from the river.

November rainfall is significantly correlated with annual adult catch. The mechanism for this relationship is not clear. It may be due to decreased salinity making more habitat available to settling postlarvae or making the estuary mouth more "attractive" to immigrating postlarvae.

7. PRESENT DATA COLLECTION

Summary is presented in Table 1.

8. FUTURE RESEARCH

Research will be directed toward the study of recruitment processes in this fishery.

* Description of effective spawning stock for P. merguiensis, and P. semisulcatus.
* Examination of larval mortality patterns, larval dispersal patterns, including primary production studies, hydrographic studies.
* Factors affecting postlarval settlement.
* Continuation of sampling for juvenile abundance in relation to rainfall and adult catch, to establish long term relationships.

TABLE 1. DATA COLLECTION - SUMMARY

Species - Penaeus merguiensis, P. semisulcatus, P. esculentus, P. latisulcatus, P. monodon, Metapenaeus ensis, M. endeavouri

Survey /Sampling	Fishery data	Other Studies
Adults		1 yr productivity
Lunar Trawl monthly	Trawl	200 plankton
Catch/trawl	Log book (daily)	Currents, tides, salinity
Size	Catch	Sea temperature
Maturity	Effort (flows fished)	Predation
	x species group	Catchability
Larvae	Sample boats	Growth and mortality experiments
Plankton net		
Lunar monthly	size	(Larvae & juveniles)
Number and size	sex	Maturity experiments
	x species	Nutrition
Postlarvae		Bacterial productivity
1 mm Plankton net	. Total landings	Seagrass
3 depths	ex processors	Effects of trawling
Fortnightly		
Numbers		
Size		
Juveniles		
Beam trawls		
2 mm/1mm		
2 m/20 mm		
Fortnightly (low tide and high tide)		
Numbers Size		
Emigrants		
Set nets 2 mm		
Fortnightly		
Numbers		
Size		

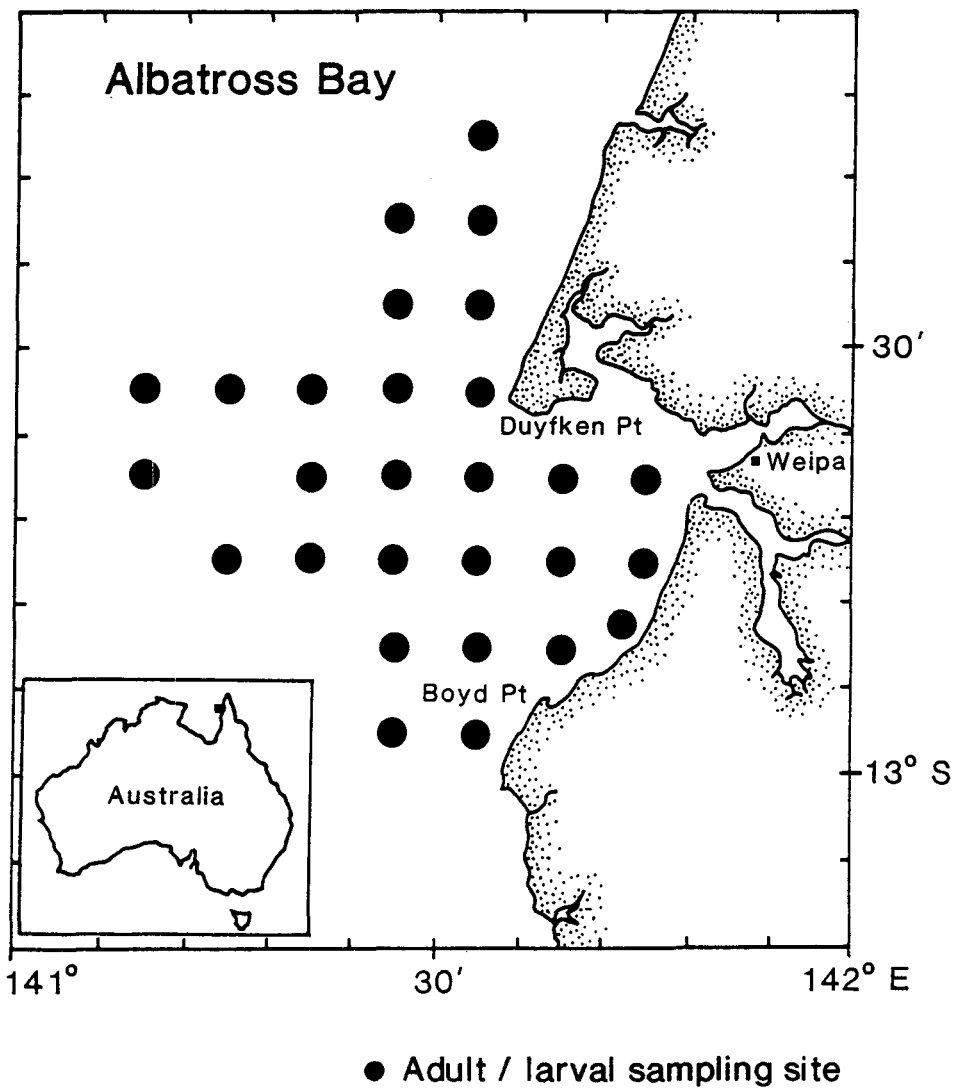

Figure 1 : PREP study site - Albatross Bay, north-eastern Gulf of Carpentaria, showing adult/larval sampling sites

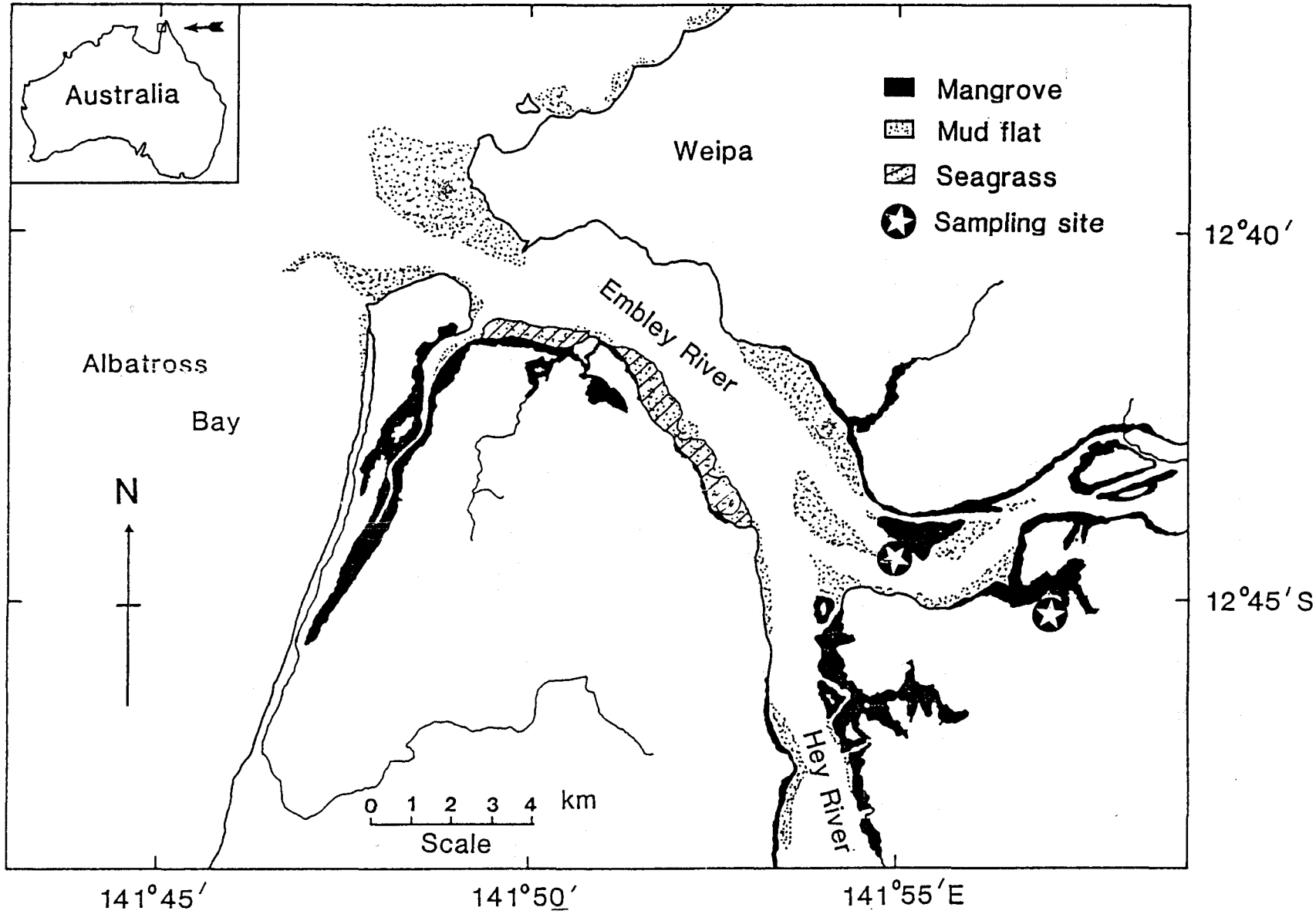

Figure 2 : Embley River estuary used for the study of postlarval and juvenile prawns

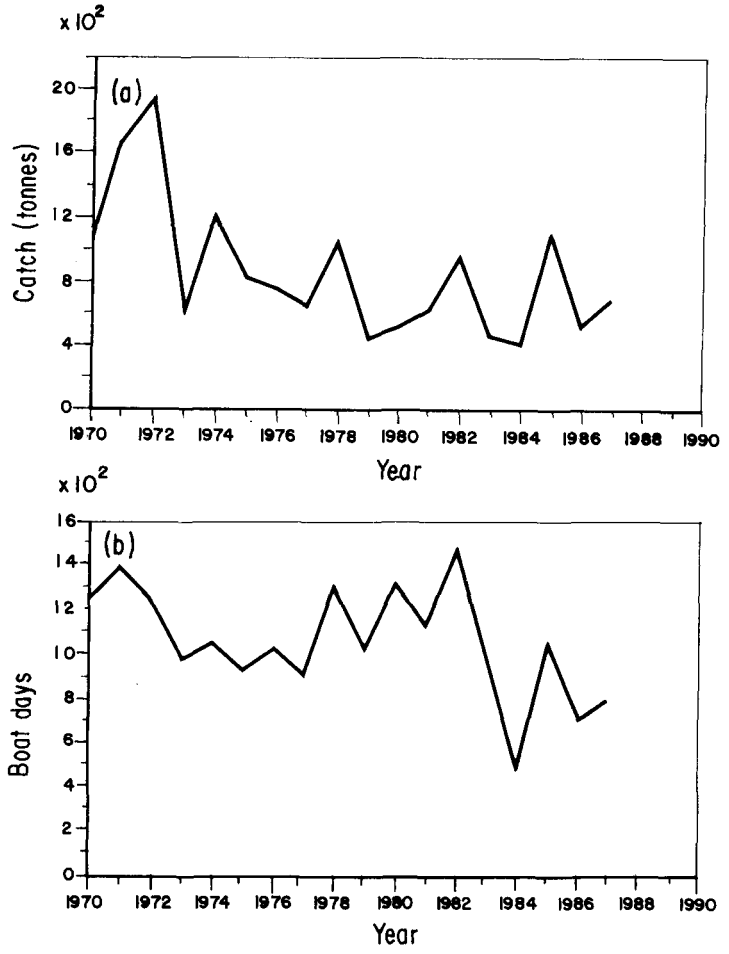

Figure 3a : Annual Penaeus merguiensis catch in Albatross Bay

3b : Annual effort (boat-days) spent searching and fishing for Penaeus merguiensis in Albatross Bay

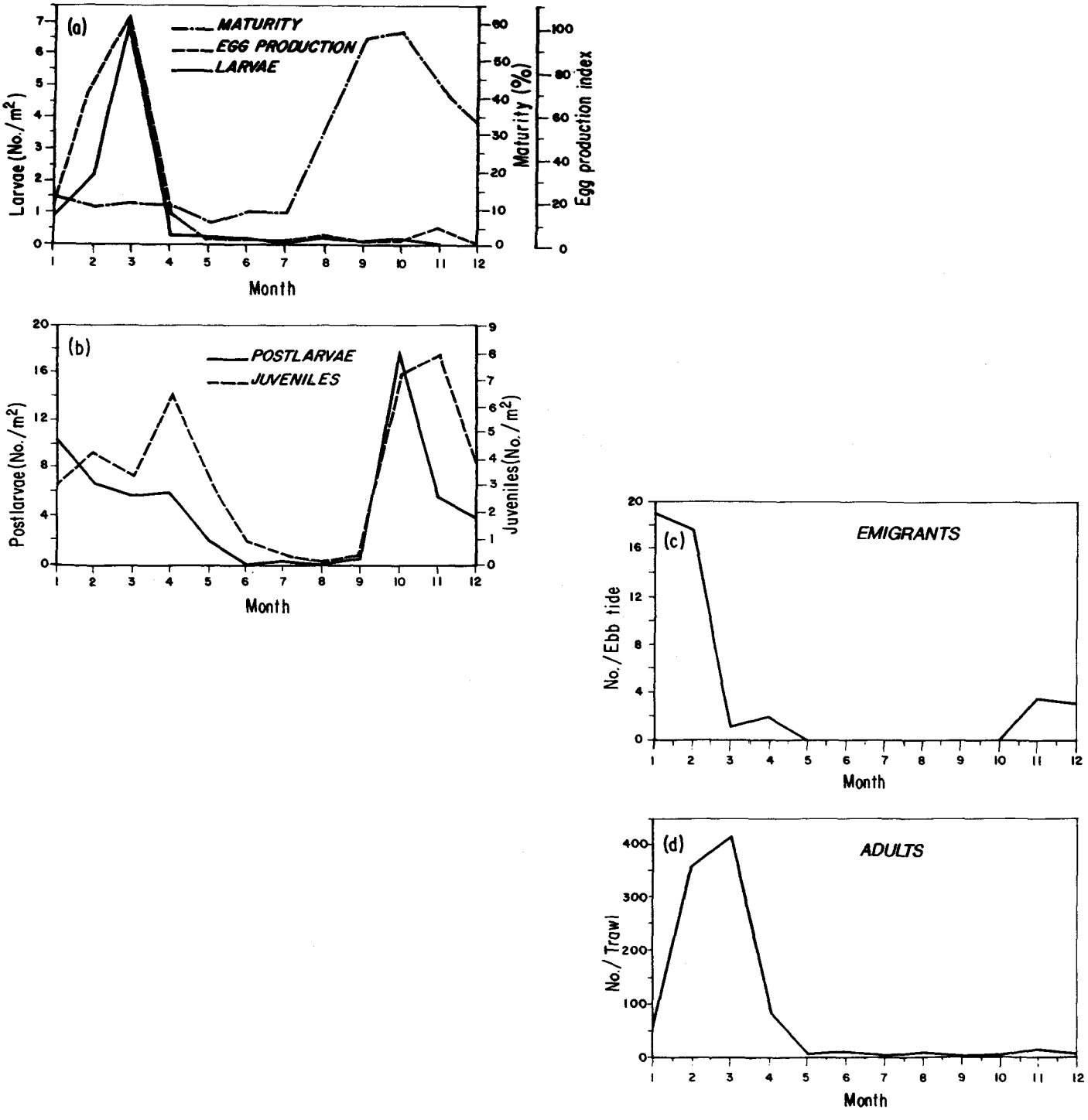

Figure 4 : Seasonal pattern in Albatross Bay of:

a. Spawning indices (percent mature and population fecundity) and larval abundance of Penaeus merguiensis

b. Postlarval and juvenile Penaeus merguiensis abundance

c. Emigrants of Penaeus merguiensis from the nursery area

d. Seasonal distribution in the abundance of adult Penaeus merguiensis. The fishing season lasts several weeks in late April

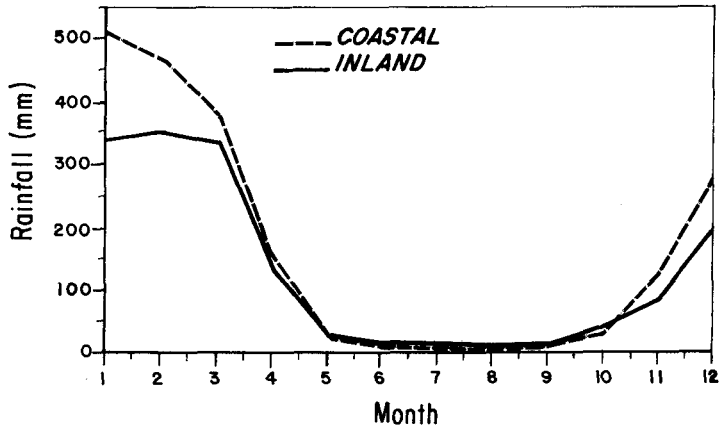

Figure 5 : Seasonal rainfall pattern for the two stations in the Albatross Bay region of the north-eastern Gulf of Carpentaria

QUEENSLAND EAST COAST

1. INTRODUCTION

Metapenaeus ensis, which was one of three species to be considered by PREP, was used in the present study because of its commercial value to Queensland's east coast fishery. Data, including reproductive periodicity, CPUE, fishing effort and adult abundance, which pertains to recruitment of this species has been obtained in recent years and is suited for analysis proposed for PREP.

2. DESCRIPTION OF THE STUDY AREA

The study area was located within established fishing grounds on Queensland's (Australia) east coast and west of the Great Barrier Reef between 18° and 21° S. Twenty sampling stations were established in this region and these were sampled by a research trawler on a monthly-lunar basis for two years. Metapenaeus ensis occurred in three stations and these were all shallow, inshore stations that ranged in depth between 17 and 20 m. The Ross and Burdekin Rivers, as well as numerous rivulets and creeks empty into the coastal region adjacent to the study area. Approximately 10 penaeid species of commercial importance are exploited from Queensland's central east coast. The present fishery is a complex multispecies fishery which not only exploits different penaeid species but also scallops (Amusium spp) and Moreton Bay Bugs (Thenus spp). The penaeid contribution to the fishery can be partitioned into an offshore and an inshore component. The offshore component consists primarily of two king prawn species; Penaeus longistylus (commercially the most important species), P. latisulcatus, and incidental catches of coral prawns Metapenaeopsis spp. The inshore component consists of two tiger prawns P. esculentus and P. semisulcatus, two endeavour prawns, Metapenaeus endeavouri and M. ensis and the banana prawn, P. merguiensis.

Effort directed upon these two components (inshore and offshore) is markedly seasonal, with the offshore king prawns being the target species during the cooler months (April to September) and the inshore species targeted during summer (October to March/April). The offshore king prawn landings, as indicated from log book data, constitute approximately 65% of the total catch from this mixed fishery. Penaeus longistylus makes up approximately 75% of this offshore king prawn catch. The remaining 35% of total landings are made up of the inshore species, of which tiger prawns contribute 25% and the two endeavour prawns and banana prawns make up the remaining 10%.

3. TRENDS IN CATCH AND EFFORT

The mixed prawn trawl fishery from Queensland's central east coast developed approximately 12 years ago. King prawn landings from this region increased rapidly between 1980 and 1987 (processor's data) with estimated landings ranging from 200 tonnes to > 2000 tonnes, conservatively. It is likely that as this fishery developed, landings of endeavour prawns also increased.

Since 1984 a voluntary log book programme has been in operation in this fishery. Approximately 30 boats, representing 15% of the vessels that exploit these grounds contribute to the log books. Combined endeavour prawn catches since 1984 have been increasing from 60 - 300 tonnes per year and of this, M. ensis was estimated to contribute 50% (30 - 150 tonnes Fig. 1a). Research sampling programme indicated that these two endeavour prawns were similar in size and were approximately, equally abundant.

Both catch and effort for M. ensis appear to be increasing since 1984 but catch per unit effort (CPUE) appears to have declined (Fig. 1b). It is unlikely that the endeavour prawns are a target species - especially while the more valuable tiger prawn species are available. It is difficult to conclude that CPUE is declining even though the data suggests that this is so. Without accurate effort, CPUE data cannot be obtained. The general trends in catch (Fig. 1a) are probably correct and reflect increasing annual landings. This fishery is still relatively young and as more vessels enter the area (as they have since 1984) it is likely that the non-targeted landings of endeavours will increase.

4. SEASONAL PATTERNS

Mean bottom sea water temperature (Fig. 2) varied from a minimum of 23.2° C in August (winter) 1985 to a maximum of 29.5° C in March (late summer) 1986. Although the sites were from inshore areas, salinity of the three sites was basically oceanic (35ppt), except for a brief period from September to October when salinity fell to around 30 ppt. The smallest female M. ensis found producing yolk (histological analysis) was 23 mm CL and all females greater than this size were consequently classed as adult. The average (from both years) percentage of stage III and IV ovary developed, was determined from only these adult females and used to indicate ovarian maturation and spawning periods. Fig. 3a reveals a clear peak in ovarian maturation in February. Ovarian maturation tended to occur during the warmest times of the year and remained very low from April to August. A possible second minor peak in maturation was observed during October.

Peak in egg production for M. ensis did not necessarily correlate with the peak in ovary maturation. The abundance of adult females (Fig. 3b) occurred in April - not when females were at their ripest. In fact, the abundance of adult females was at a minimum when

the highest frequency of ripe females occurred. An egg production index based upon a combination of

(a) % ripe females,
(b) abundance of adults and possibly
(c) % spermatophore impregnated would provide a better indication of egg production.

Abundance of sub-adults (< 23 mm CL) displayed a similar pattern to that of adults; with a peak occurring in April. This is unusual because this younger, smaller cohort would normally be expected to occur earlier in the year than the adult peak. This result may be partially due to pooling males and females. The size class frequency data, collected from the research programme indicate that females grow much larger than males-females of 41 mm CL were consistently sampled while only one male M. ensis greater than 31 mm CL was found.

5. SELECTION OF RECRUITMENT INDICES

Annual commercial landings of M. ensis from this mixed prawn fishery are not a reliable source for either spawning stock size or recruitment indices. Metapenaeus ensis is pooled with M. endeavouri in commercial catches and so if that proportion of the catch due to M. ensis is to be determined from the commercial catches they should be sampled (by researchers) all year round.

Catch of the false endeavour prawn is also influenced by effort and, as mentioned earlier, the endeavour prawns in this fishery are probably not a target species and the amount of effort applied is unknown. The most appropriate methods for estimating recruitment and spawning stock indices for M. ensis from this central Queensland region would be from a continuous research survey. A research survey could determine when certain sized prawns (recruits) first enter commercial grounds, and it would also provide abundance on spawning stocks.

6. INTERANNUAL VARIABILITY

No information available.

7. PRESENT DATA COLLECTION

No information given.

8. FUTURE RESEARCH

The endeavour prawns M. ensis and M. endeavouri generally occur together and are exploited together in fisheries all over the northern half of Australia. Fishermen do not differentiate between the two species and so if landings of these individual species are to be monitored then the proportion of the catch due to each species should be monitored periodically. Alternatively a research sampling programme could be initiated.

At present, egg production indices have not been determined for M. ensis in this fishery. However this will be carried out in the near future. Periodicity in egg production can then be compared with the abundance of small recruits determined from size class frequencies generated in the sampling programme.

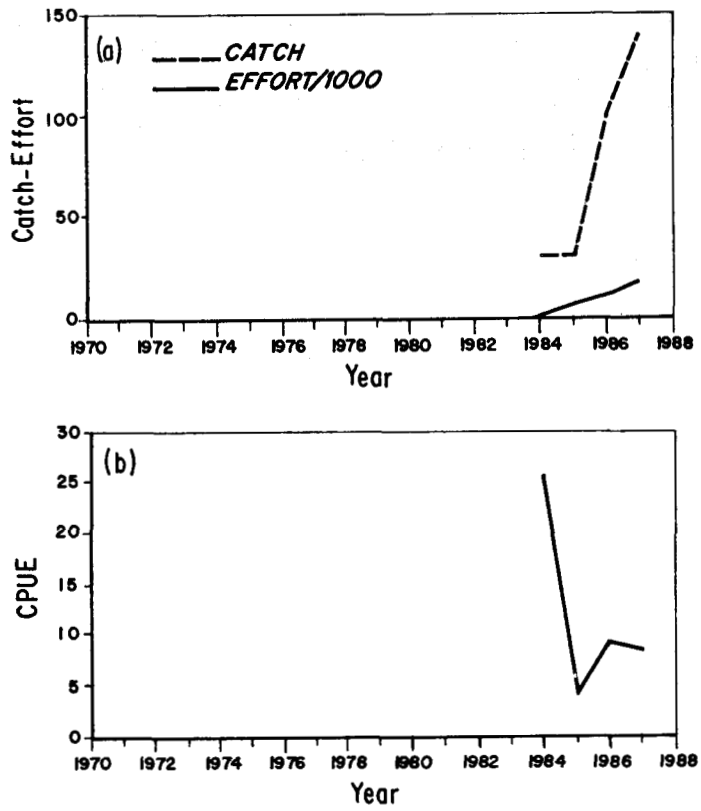

Figure 1a : Catch and effort for Metapenaeus ensis from the Queensland east coast

1b CPUE for Metapenaeus ensis from the Queensland east coast

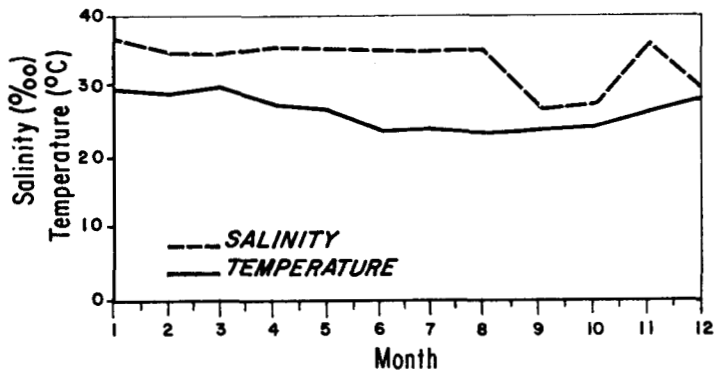

Figure 2 : Seasonal cycle of temperature and salinity for the Queensland east coast

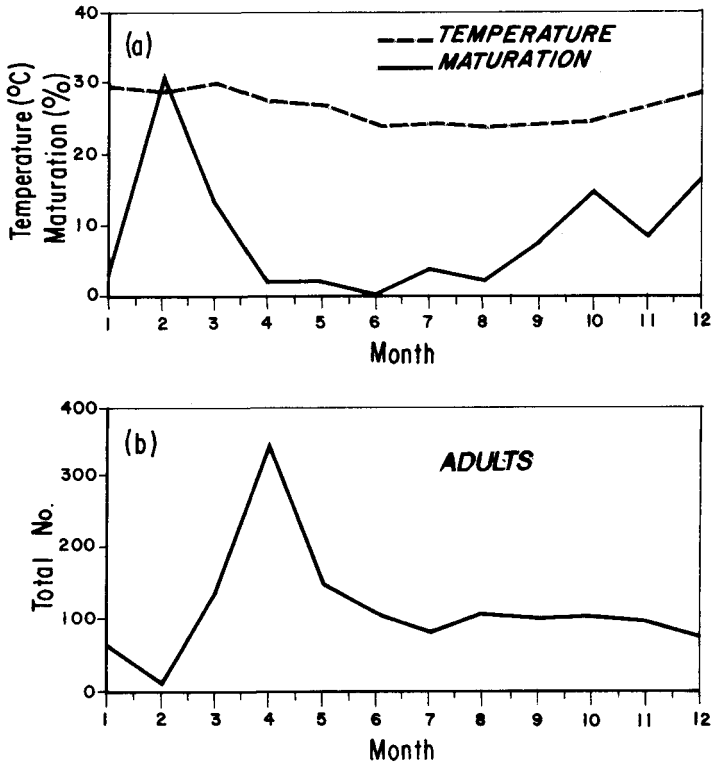

Figure 3 : Seasonal patterns of Metapenaeus ensis abundance:
a. Maturity (percent ripe)
b. Adults

ANNEX VIII

NATIONAL RESEARCH REPORT

INDONESIA

1. INTRODUCTION

Prawns form one of the most important fisheries in Indonesia. This fishery developed rapidly with the introduction of trawling in the late 1960s. Although trawling has been banned since 1980, this fishery still plays an important role in contributing devisa earning to the country.

The prawn fishery in the Indian Ocean side is centred in the Cilacap area. This area is characterised by large area of mangrove. The catches are dominated by Penaeus merguiensis. Data on the biology and fishery of this species have been collected for many years, however, thorough analyses of the data are needed.

It is for this reasons that Cilacap prawn fishery has been selected as the study site for the PREP Workshop.

2. DESCRIPTION OF THE STUDY AREAS

The shelf along the south coast of Java is generally very narrow. Its widest extension is found in the Cilacap area where a plain reaches the ocean (Fig. 1). In the western part of this plain there is a brackish water lagoon (about 4,000 ha), the Segara Anakan, surrounded by mangrove covered wetlands (about 14,000 ha). The area receives its fresh water from various rivers, among which the Citanduy is the most important (Fig. 2). The main south coast's prawn grounds are situated in the direct vicinity of the above described intertidal area: to the south west Pananjung Bay and to the east Teluk Penyu-Gombong grounds.

Fishing takes place mostly within 25 km from the shore at depths ranging from 3 m to about 50 m. Teluk Penyu Bay has a mud bottom, while in Pananjung Bay a mixture of sand and mud is found. The total surface area of the fishing ground (to the 50 m isobath) is estimated to be about 300 km^2. The rainy season usually starts in September and peaks in October to December and then decreases. The months June through August are regarded as the dry period of the year. The tide of the Indian Ocean at Cilacap is diurnal and has a mean range of about two metres.

More than twenty species belonging mainly to the family Penaeidae support the Cilacap prawn fishery, but only six species constitute the economic basis of the fishery. These are grouped into three groups as follows:

- Jerbung (banana, or white prawn): consists mostly of Penaeus merguiensis, but also includes P. chinensis, P. monodon and P. semisulcatus.
- Dogol (endeavour prawn): consists of Metapenaeus ensis and M. elegans.
- Krosok (mix of small species of prawns): mainly consists of Parapenaeopsis, M. dobsoni and Solenocera.

P. merguiensis constituted about 15% of the total prawn catch during the trawl era and 30% of the total prawn catch during the trammel net era.

3. TRENDS IN CATCH AND EFFORT

Based on the historical data, the Cilacap prawn fishery can be divided into two phases; trawl era and trammel net era. During the trawl era, the catches are dominated by the contribution of trawl while after the trawl ban, the prawn catches were mainly contributed by trammel net fishery.

Data on catches and effort were collected from the Cilacap fish landing place twice per week during the trawl era and fortnightly during the trammel net era. Effort is presented in number of boat-days, and therefore the CPUE is presented in catch per boat-day.

Trends of CPUE can be seen from Fig. 3. During the trawl era the CPUE tended to decrease from year to year, while during the trammel net era the CPUE was more stable.

Monthly catch and effort data show that both monthly catch and CPUE are high during the months of September through December. This seasonality shows a similar trend during trawl era and trammel net era.

4. SEASONAL PATTERNS

Maturity

Based on the monthly average of maturity stages (in percentage), the spawning season of P. merguiensis in the Cilacap area can be determined. Spawning occurs all year round with peaks in March-April, August and November. Larvae peaked in May at one site and in August at another (Fig. 4a).

Benthic postlarvae

Data on the benthic postlarvae collected from the east and west entrances during the flood tide shows that the immigration of the benthic postlarvae also occurs throughout the year, but with peaks in February and June (Fig. 4b).

Number of juveniles emigrating from the Segara Anakan lagoon to the sea was sampled during the ebb tide by using "jaring apung" (bag net). The data show that the emigrating juveniles occur all the year round with significant peaks in December and January (Fig. 4c).

Adults

Data on the adult prawn caught in the offshore area show that the peak fishing season for adult P. merguiensis occur during the months of September through January (Fig. 4d). These peaks coincide with the wet season of the northwest monsoon (Fig. 5).

The catches of larvae, juveniles and adult as well as the maturing stage (stage 3 and 4) of P. merguiensis in the Cilacap area seem to show a marked seasonal pattern, although factors governing this pattern are still not studied. The data also show that there is a six month time delay between the spawning season (maturing stage) and fishing season.

6. SELECTION OF RECRUITMENT INDICES

No information given.

7. PRESENT DATA COLLECTION

Present data collection is summarized in Table 1.

8. FUTURE RESEARCH

Past studies were designed to evaluate the status of the fishery. In the future it is important to know the dynamics of the larval and juvenile stages so that studies of all life stages are covered. At the same time various environmental factors will be studied to know which factors are governing the dynamics of the young prawn.

TABLE 1. DATA COLLECTION - SUMMARY

Species - Penaeus merguiensis. P. monodon, Metapenaeus ensis, M. elegans, Parapenaeopsis

Survey/Sampling	Fishery data	Other Studies
Larvae/Postlarvae	Trawl - then trawl	Currents
Bottom plankton nets	net, Bag net	Tides
(Flood tide)	Landing site	Salinity
150 p/hr	Daily boat number	Temperature
	Sample boats	Heavy Metals
Emigrants	(Trawlers 2x/wk)	Sedimentation
Bag nets (2mm mesh)	(Trammel 2x/	Mangroves
No./hr	monthly)	Catchability
	- Size	Meroplankton
	- Maturity	

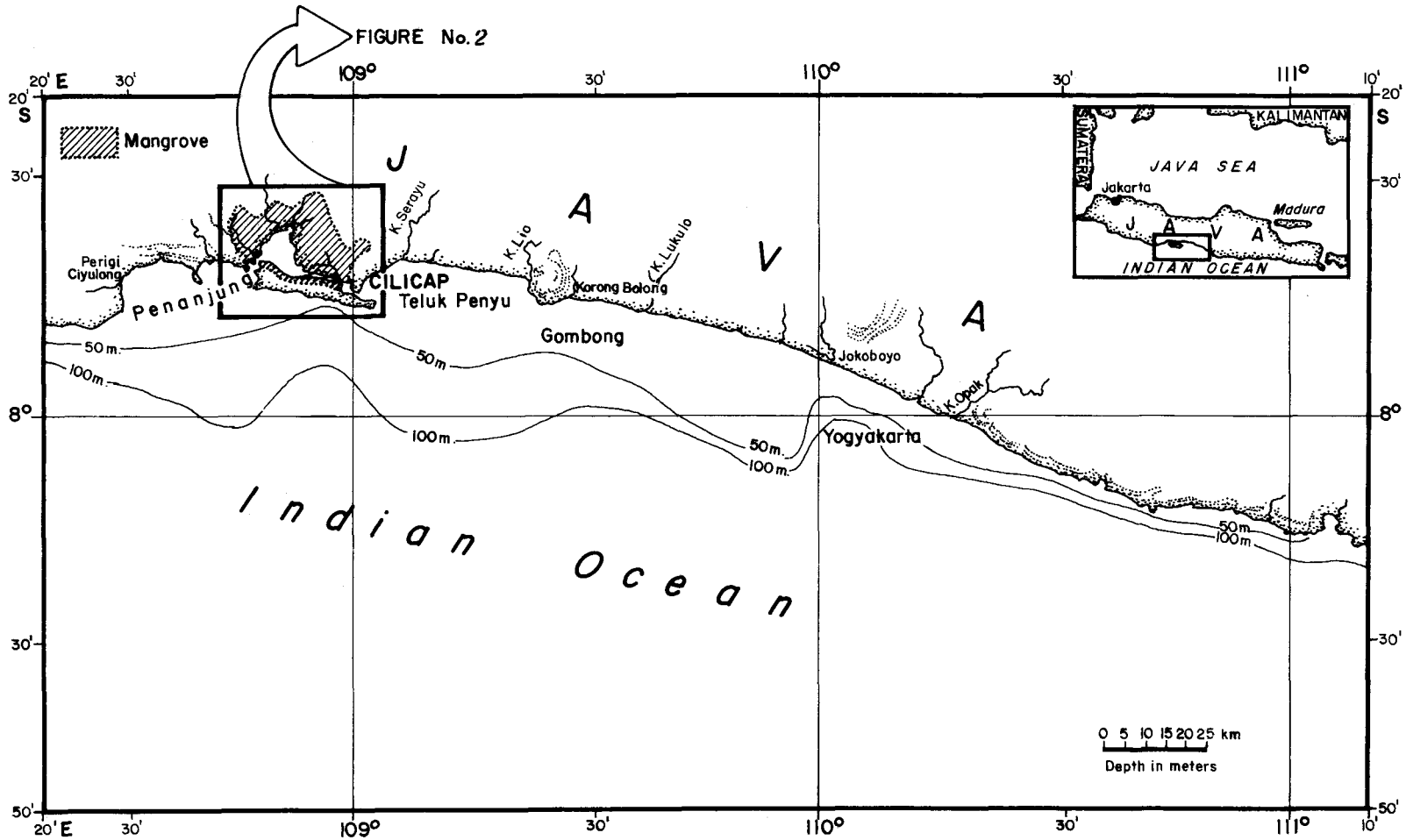

Figure 1 : Map of the prawn fishing grounds along the south Java coast

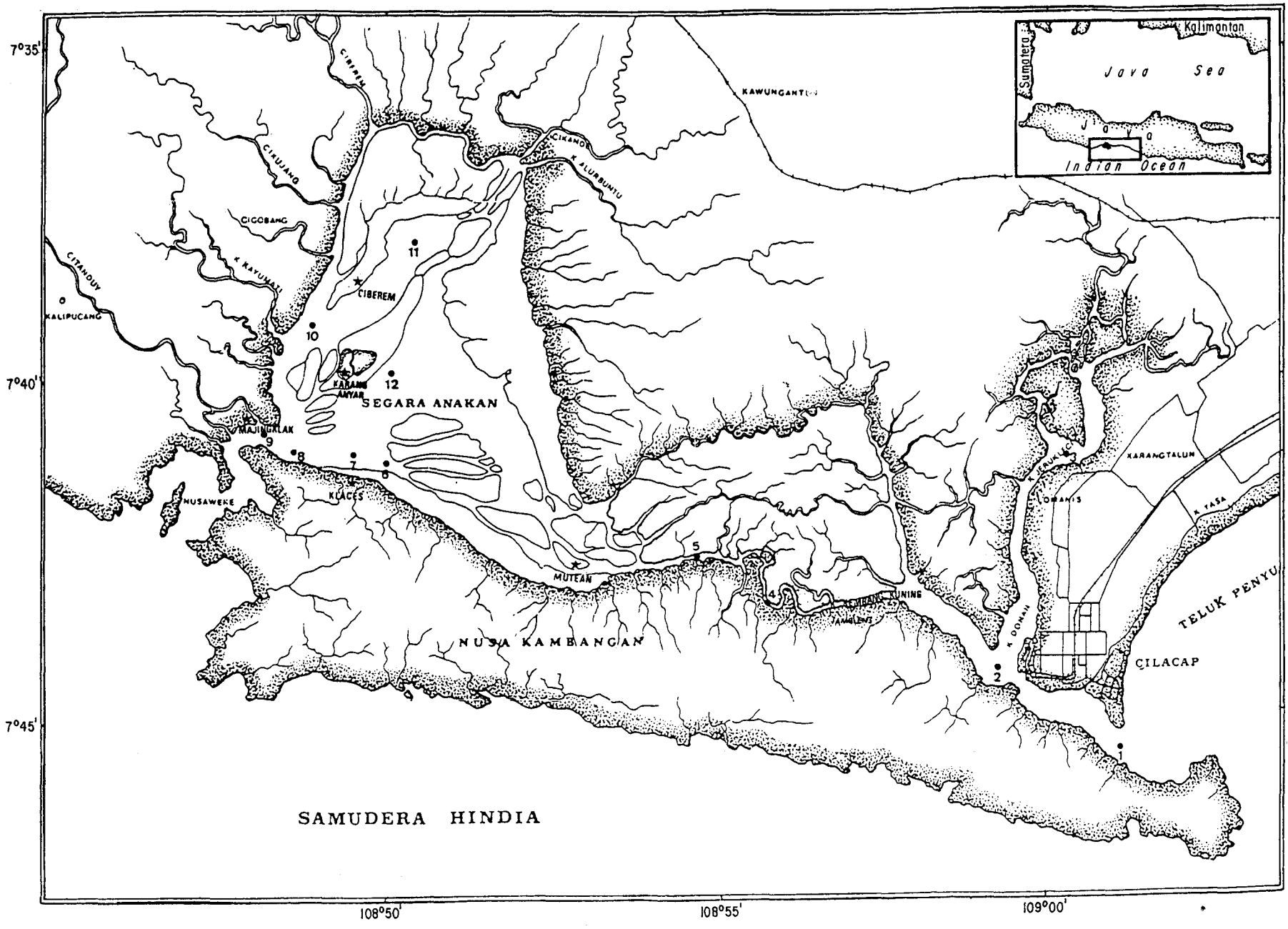

Figure 2 : PREP study site at Cilicap, south Java

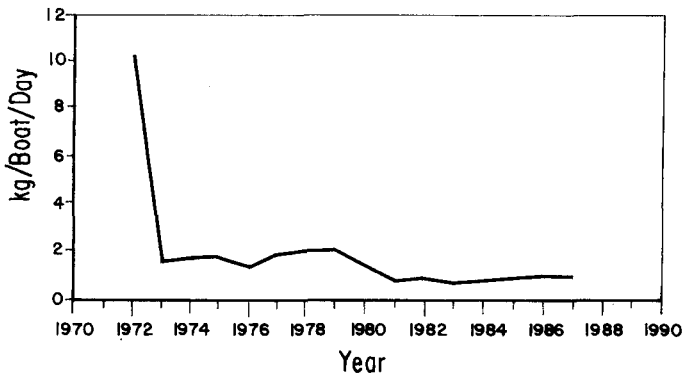

Figure 3 : Annual trend in CPUE for Penaeus merguiensis (1972-1979: trawl era, 1981-1987: trammel net era) at Cilicap

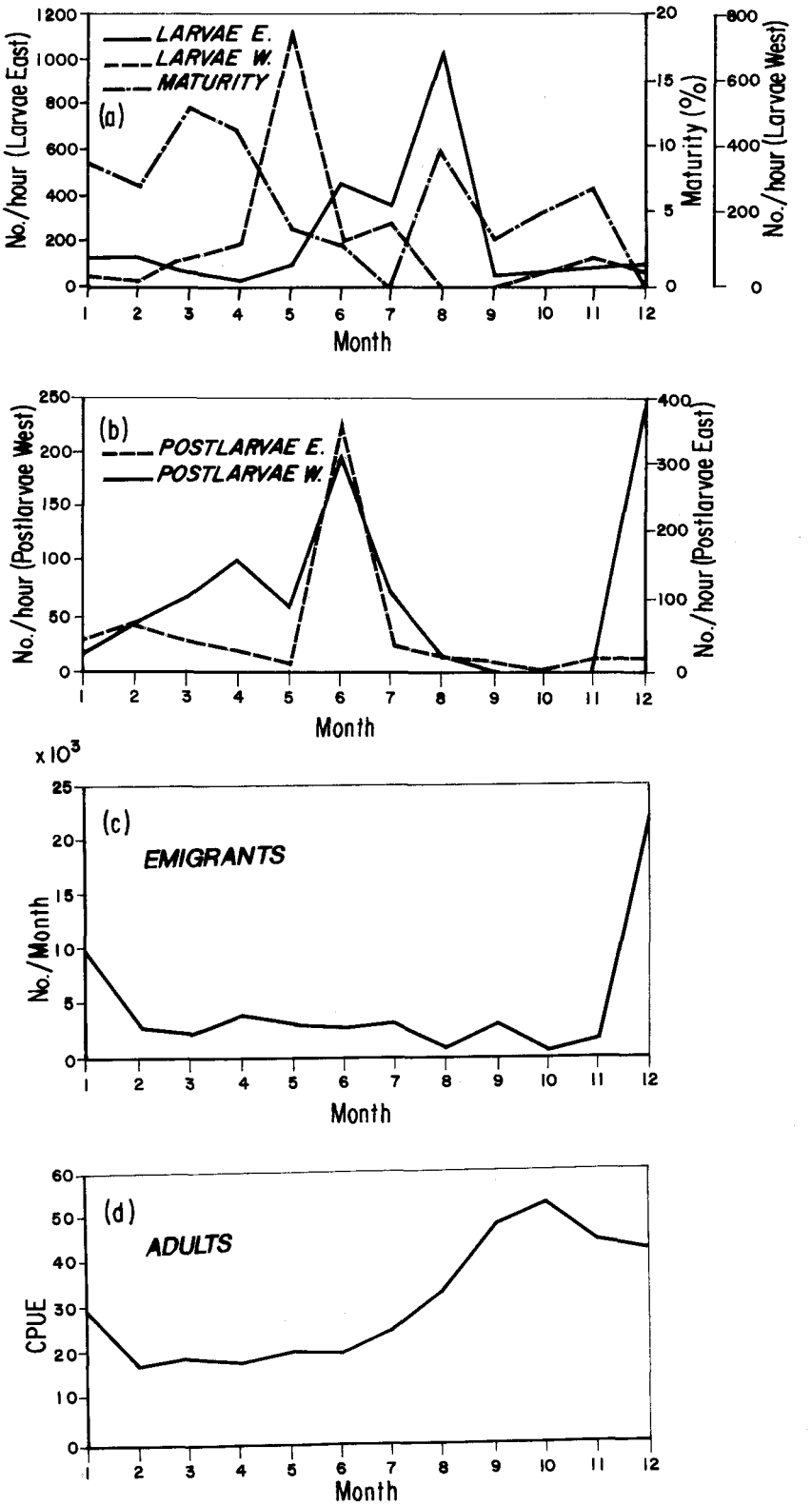

Figure 4 : Seasonal patterns in the abundance of Penaeus merguiensis:

a. Spawning and larvae
b. Postlarvae
c. Emigrating juveniles
d. Adults

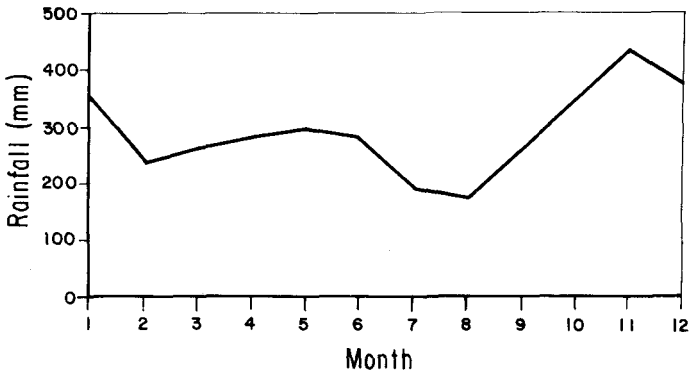

Figure 5 : Average monthly rainfall for the Cilicap region

ANNEX IX

NATIONAL RESEARCH REPORT

MALAYSIA

1. INTRODUCTION

Penaeid prawns constitute an important proportion of the marine fisheries landings in Peninsular Malaysia, due to their high economic value, particularly on the west coast of Peninsular Malaysia where around 50,000 to 60,000 tonnes of penaeid prawns are landed annually. The penaeid prawn landings on the east coast of Peninsular Malaysia are much lower, in the region of 5,000 - 6,000 tonnes annually.

Penaeus merguiensis is landed both by traditional passive fishing gear like trammel nets and the more active gear such as trawl nets on the west coast of Peninsular Malaysia. The project study area in the State of Perak on the west coast of Peninsular Malaysia was selected on the basis of the diversity of fishing gears operated by the fishermen which harvest prawns from the juvenile to the adult stages of its life-history. In addition, the extensive coastal mangrove swamp area and the high penaeid prawn landings from the area also provide a suitable study area. While P. merguiensis may not be the dominant species landed in the area, they constitute an economically high value species.

In addition, the area had also been selected for a pilot FAO/TCP project on Area Fisheries Management.

As this area has an important prawn fishery, it is felt that the data and information that would be obtained from the PREP project would provide the necessary information for more effective implementation of the FAO/TCP Area Fisheries Management pilot project.

2. DESCRIPTION OF STUDY AREA

The study site chosen for the PREP project is located on the west coast of Peninsular Malaysia in the Larut-Matang District of the State of Perak between Latitute 4°34'N and Latitude 5° 0'N. The project area is characterised by an extensive mangrove coastal coastline with numerous estuaries and a large coastal mudflat (Fig. 1).

Penaeus merguiensis is exploited by a number of fishing gears which include passive traditional fishing gears like the bag nets, trammel nets, and shallow-water seine nets to the more active fishing gears like push nets and prawn trawl nets. Fishing is carried out throughout the year.

The push nets are operated by the fisherman in the estuaries and fringes of the coastal mangrove swamps. Juveniles of P. merguiensis are landed by this fishing gear. The bag nets are operated at the mouths of the estuaries taking the emigrant P. merguiensis as they move out of the estuaries with the ebb tide. Shallow-water seine nets are operated just

off the mouths of the estuaries. The trammel nets are operated in slightly deeper waters off the coastal mangrove swamps while the prawn trawlers operate further offshore in deeper water. However, the trawl fishing area also overlaps the trammel net fishing area. The P. merguiensis subadults are caught by the shallow-water seines while the adults are taken by the trawl nets and trammel nets.

3. TRENDS IN CATCH AND EFFORT

Graphical representation of the annual catch and effort data of Penaeus merguiensis collected from the various gears operating within the study area from 1981 to 1987 are given in Figs. 2 to 9.

3.1 The pushnets

Pushnets are traditional fishing gear operated in the estuary and on the fringe of the mangrove swamps by small-scale fishermen inhabiting the coastline of Larut Matang. They have the added advantage of being very selective in their catch, taking mostly juvenile prawns, of which up to 74% consist of Penaeus merguiensis.

Analysis of the catches from the pushnets indicate a yearly yield of around 50 tonnes of prawns from the year 1982 to 1986 (Fig. 2a). The 1987 catch data however, rose to 220 tonnes probably indicating a massive influx of prawn juveniles into the mangrove swamps, possibly as a result of better enforcement control by the fishery management on the trawl fishery. [This implies a demonstrable stock:recruitment relationship Ed.].

Around 170 units were estimated to be operating between 1984 and 1986. This reduced slightly to around 130 units in 1987 (Fig. 2b).

3.2 The Trawlers

Analysis of the species of prawns caught by trawlers showed that Penaeus merguiensis constituted around 5% of the total catch. Annual catches from trawlers operating in Zone A (area within 5 miles from shore) showed a decline between 1982 and 1986, (Fig. 3a) which was followed by a sharp rise in 1987, while those operating in Zone B (area between 5 miles and 12 miles offshore) showed a somewhat constant catch between 1982 and 1986 and again a sharp rise in 1987 (Fig. 4a).

In 1981, the number of trawlers operating in Zone A was estimated at around 380 units, which was gradually reduced to around 100 units between 1984 and 1987, as a means of improving the prawn fishery (Fig. 3b). Trawlers operating in Zone B increased from slightly below 200 units in 1981 to nearly 600 units in 1987, to encourage fishermen to fish in deeper waters (Fig. 4b). This was done to better utilise the fishery resources in deeper waters, and to reduce fishing pressure exerted by the trawlers in the prawn-enriched waters near to shore. To ensure that all the rules and regulations were complied with by the fishermen, stricter enforcement control by the fisheries department enforcement control unit has been imposed from 1985 onwards. This was probably one of the factors involved which results in the improvement of

the prawn fishery as a whole, as indicated by the rise in the catch in the landings of 1987.

3.3 Bagnets

Bagnets are static fishery units placed by the fishermen at the mouth of the estuary and rivers leading into the mangrove swamps of the study area. Their mode of operation is closely synchronised to the spring tides as they depend largely on the movement of the water to push the migrating prawns into the net.

Annual catches of Penaeus merguiensis from bagnets between the years 1983 - 1987 again indicate a similar trend to that of the previous gears (Fig. 5a). Catches seem to remain relatively constant (with only slight normal fluctuations) between the years 1983 to 1986, but rose sharply in the landings of 1987. The number of units in operation increased from around 6 units in 1983 to around 20 units in 1985 - 1987 (Fig. 5b). The increase in the catch of 1987 was probably related to the better handling of the trawl fishery by the management concerned.

3.4 Trammel nets

Annual catches of Penaeus merguiensis using this gear, were observed to be rising from 1981 to 1987, with the highest catch of near to 400 tonnes (Fig. 6a). This is probably achieved by allowing an increase in the number of fishing units from around 100 units in 1981 to just below 400 units in 1987 (Fig. 6b).

Penaeus merguiensis was observed to be the dominant species in the catches, constituting an estimate of around 76% of the total catch of prawn.

3.5 Shallow-water seine nets

These are traditional prawn fishing units of secondary importance, operated by fishermen in the waters along the coastline of the study area. Annual catches observed were in the region of 200 kg with effort of around 200 units in operation (Fig. 7a and b).

The absence of the 1987 data causes some difficulty in comparing the annual catch trend with that of other gears, although a decline in the catch was observed for the years of 1985 and 1986.

3.6 Driftnets

Annual catches by driftnets between the years 1981 to 1986 show a marked but gradual decline in the years concerned. The number of units in operation was estimated at around 400 in the years 1981 to 1983, but reduced to around 200 units after 1984 (Fig. 8a and b). As with the shallow-water seines, no data were available to indicate the performance of the driftnet fishery for the year 1987.

3.7 All gears

Annual total catches of Penaeus merguiensis from all gears analysed between the years 1981 to 1987 show a fluctuation between 1981 to 1986 and a marked increase in the catches for the year of 1987 (Fig.

9). This observation seems to indicate a good performance by the fishery as a whole, and this is attributed to better fishery management control on the trawl fishery.

4. SEASONAL PATTERNS

The catches per unit effort (kg/boat/day) of the various fishing gears were used as indices of abundance for the different life history stages. These were averaged over the years 1981 to 1987 for each month of the year.

Juveniles did not exhibit any distinct periods of high abundance (Fig. 10a). The emigrants appeared to have one peak period of abundance during the months of February, March and April, while the subadults exhibited a peak period of abundance between February and March (Fig. 10b and 10c). The adults also appeared to have only one peak period of abundance, i.e. from the months of May through June as indicated by the CPUE of the trawlers (Fig. 10d), while the CPUE of trammel nets did not indicate any seasonal abundance of the adults (Fig. 11).

In the case of rainfall, two high rainfall periods are evident during the year. The first period during the months of March and April, while the second occurs during the months of October, November and December (Fig. 12).

The peak period of rainfall during March and April corresponded with the peak periods of abundance of emigrants, subadults and adults (caught by trawlers) while no exceptional abundance of prawns was observed during the second rainfall peak period of the year during the months of October, November and December.

The correlation between peak abundance of the prawn CPUE with peak rainfall during the months of March - May indicate that there may be some relationship between the high abundance of P. merguiensis and heavy rainfall.

As mentioned earlier, the P. merguiensis is fished throughout the year by all the fishing gears.

5. SELECTION OF RECRUITMENT INDICES

The penaeid prawn fishery in the study area is very intensive, particularly the prawn trawl fishery. In addition to the trawl fishery which exploit the adult prawns,the push net fishery in the estuarine areas of the study area also exploit the juvenile prawns. In view of the fact that these fishing gears take the adults and juveniles, the recruitment indices that could probably be used would be direct estimates of the total catch or abundance of the prawns. However, indirect length based cohort analysis would be more useful in the study area for the estimation of recruitment. This would require

length frequency distribution data on a monthly basis with samples taken along a transect perpendicular to the coastline from the estuaries towards the offshore waters.

6. INTERANNUAL VARIABILITY

No information was analysed during the workshop.

7. PRESENT DATA COLLECTION

Present research activities concerning prawns that are being carried out are as follows: (Table 1)

(i) Surveys

A prawn survey is carried out once a year to determine the standing stock status and prawn species composition in the coastal waters of Malaysia. This is important to ensure the prawn resource stock does not undergo any extensive and irreparable damage due to the activities of the trawlers.

Data collected include the identification of the various species of prawns, length frequency and male to female sex ratio. Due to the trawling being done on an hourly basis, CPUE of the prawns is estimated as kg/hr.

(ii) Commercial data (from trawlers)

Data are collected on a monthly basis from the major landing sites and includes landing, species composition and biological data from 4 common species: P. merguiensis, P. semisulcatus, M. affinis and M. ensis. At least 5 boats are sampled every month.

(iii) Research

Research activity currently being undertaken involves a study of diurnal variation in the catchability of prawns. Data collected includes: identification of prawn species, landings/total catch, length frequency and the male:female sex ratio at various times of day and night.

8. FUTURE RESEARCH

It is evident that the management of the prawn resources would require more information on the recruitment of the prawn into the fishery.

In order to provide the necessary data for the better understanding of the penaeid prawn recruitment dynamics in the project study area, a very intensive research programme is envisaged to collect and analyse data on the effects of fishing and environmental factors that have a significant impact on the prawn recruitment and annual production/catch in the study area.

The future research in the study area would encompass the following:

(a) Determination of any true correlation between seasonality in the abundance of the different life history stages to any seasonality in environmental parameters that might affect the abundance of any life history stages.
(b) Determine factors relevant to the recruitment of the penaeid prawn including prawn behaviour, catchability, etc.
(c) Determine appropriate indices of spawning and recruitment.
(d) Modelling of recruitment in relation to appropriate environmental/biological parameters.

TABLE 1 DATA COLLECTION - SUMMARY

Species - Penaeus merguiensis, P. semisulcatus, Metapenaeus affinis, Metapenaeus ensis

Survey/Sampling	Fishery Data	Other Studies
Sub-Adult/Adults	Juveniles Sub-Adult/Adults	
Trawl	Trawl, trammel net, pushnet	Catchability
Annual survey	Bag net	Aquaculture
Catch/hour	Monthly landing site	
Size	catch/sample boat	
Sex	No. of boats	
x Species	Total catch/day x w. days	
	X Species group & gear	
	Selected Species (P.merg, P.semi M.affinis, M.ensis)	
	Size	
	Sex	
	mat.	

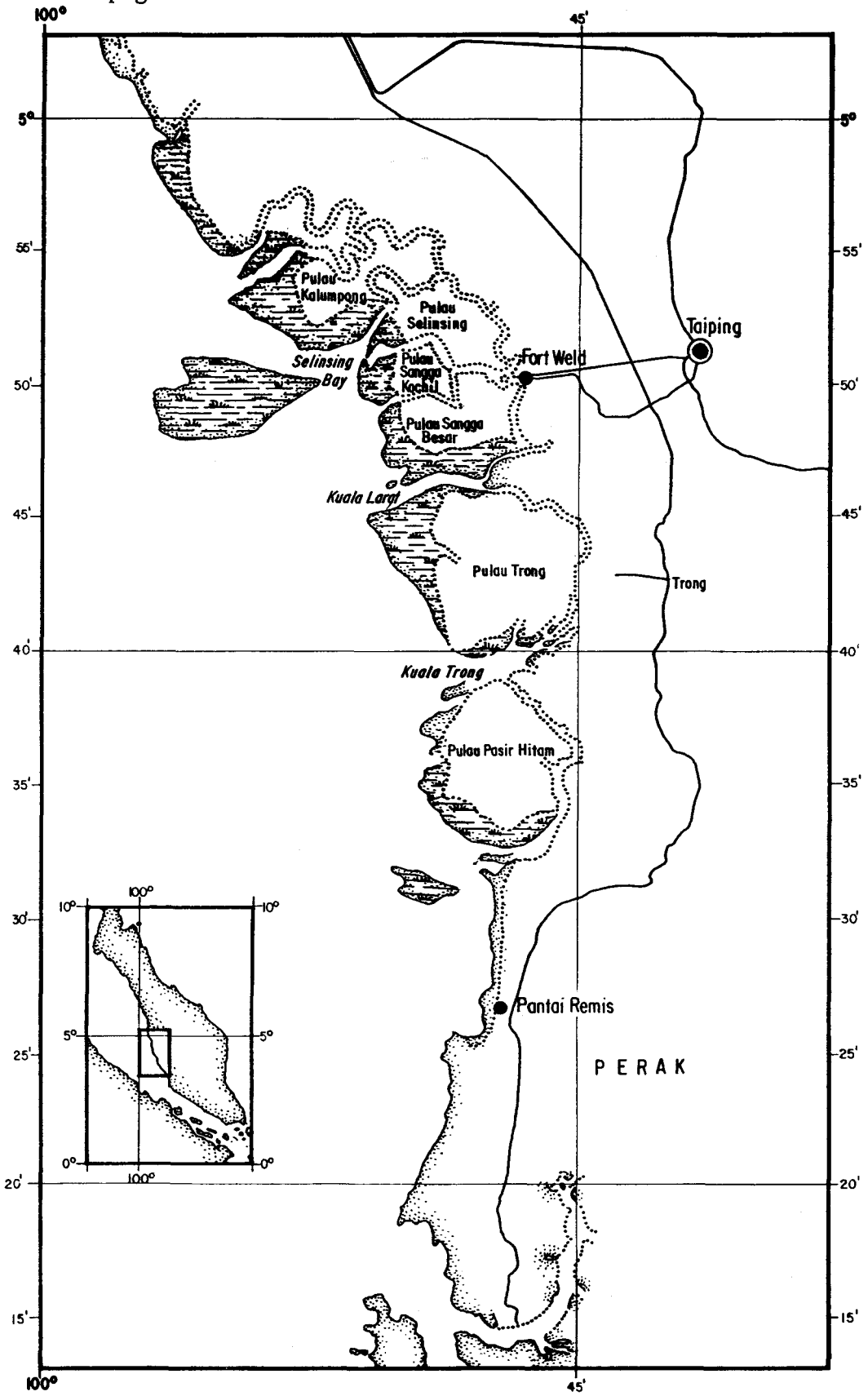

Figure 1 : Map of the Larut-Matang PREP study site on the western coast of Malaysia

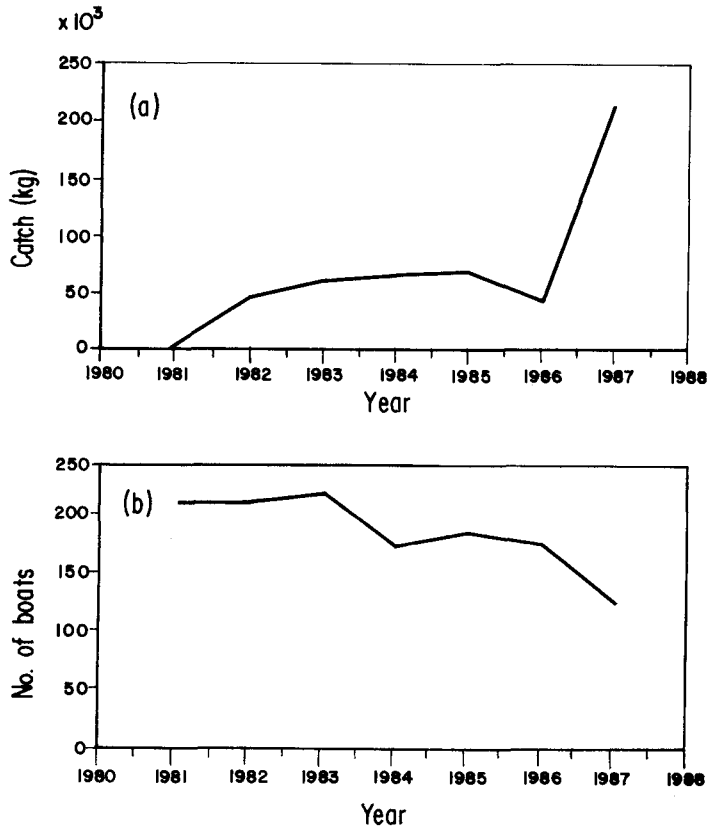

Figure 2 : Annual push net catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

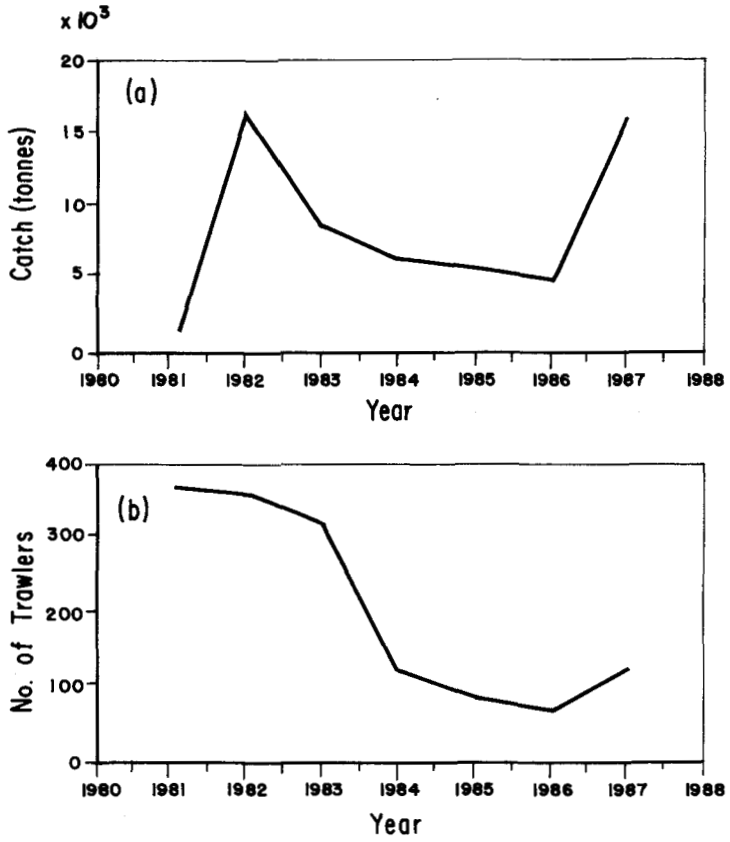

Figure 3 : Annual trawl (Zone A) catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

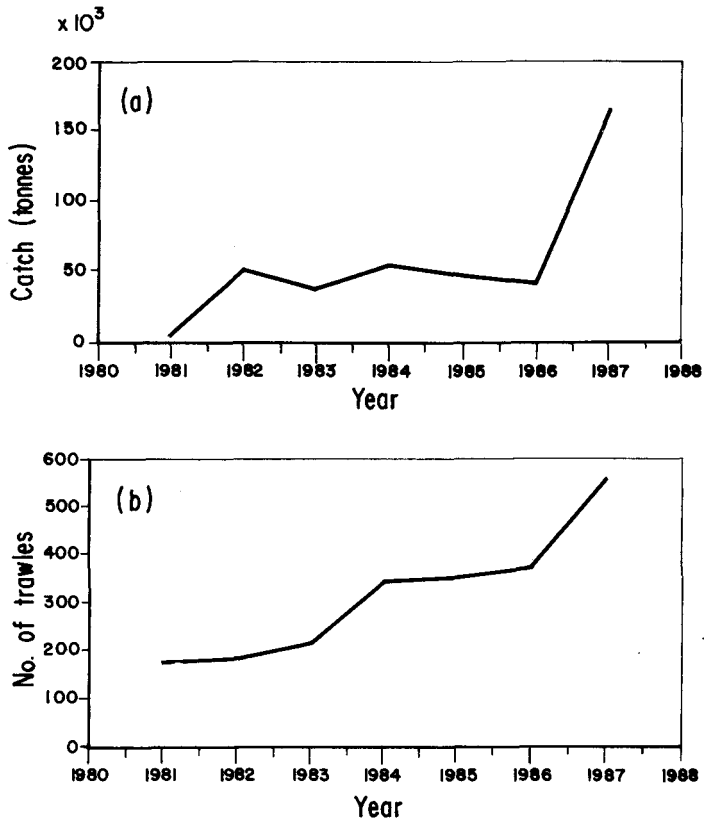

Figure 4 : Annual trawl (Zone B) catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

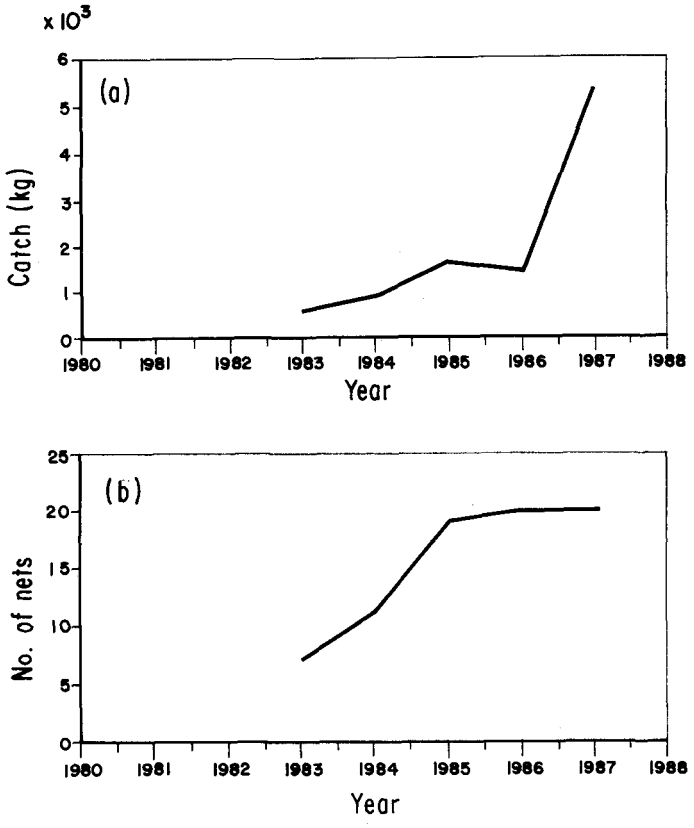

Figure 5 : Annual bag net catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

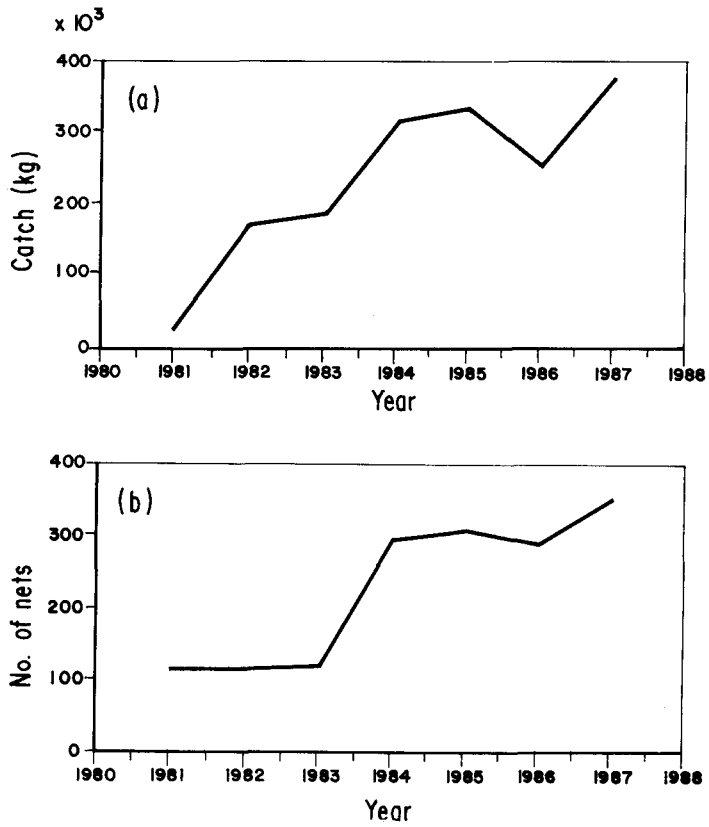

Figure 6 : Annual trammel net catch and effort data for Penaeus merguiensis in the Larut-Matang District.

a. Catch

b. Effort

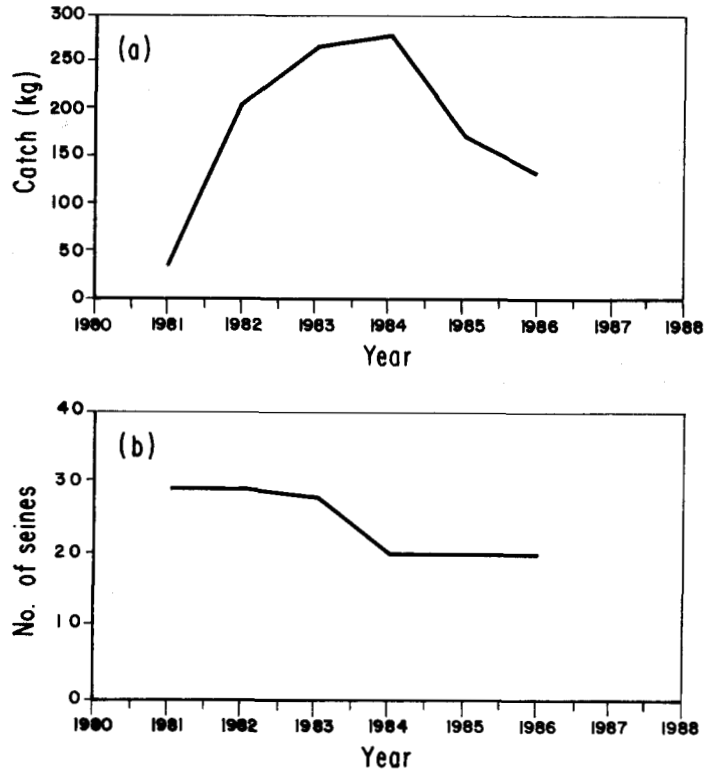

Figure 7 : Annual shallow water seine net catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

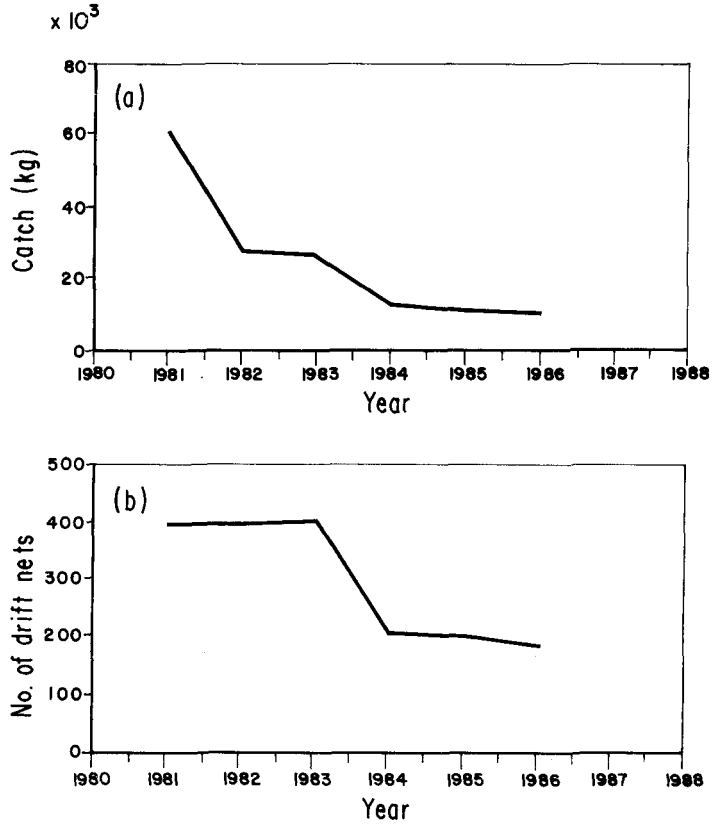

Figure 8 : Annual drift net catch and effort data for Penaeus merguiensis in the Larut-Matang District:

a. Catch

b. Effort

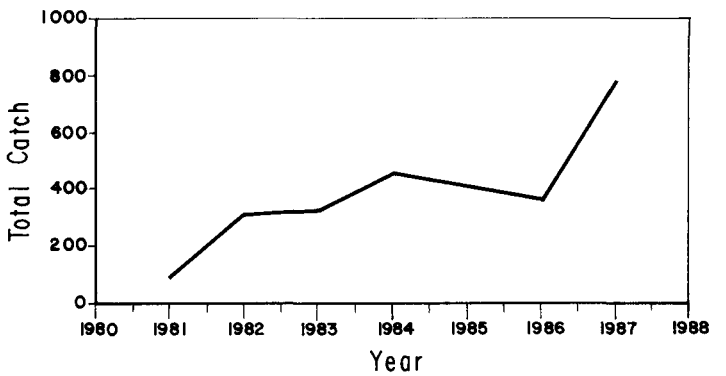

Figure 9 : Annual total catch data for Penaeus merguiensis in the Larut-Matang District

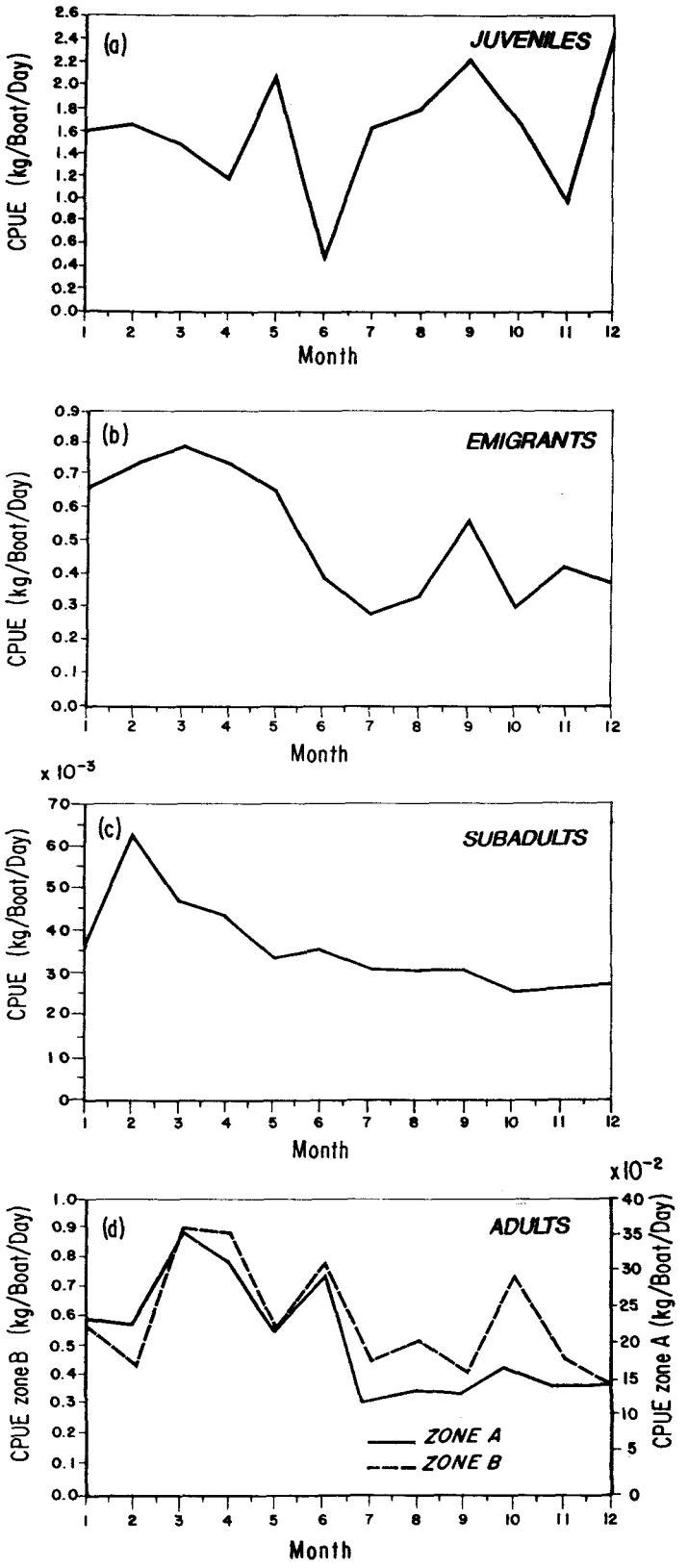

Figure 10 : Seasonal pattern of abundance of Panaeus merguiensis:
a. juveniles (push net)
b. emigrants (bag net)
c. subadults (shallow water seine)
d. adults (trawler, Zone A & B)

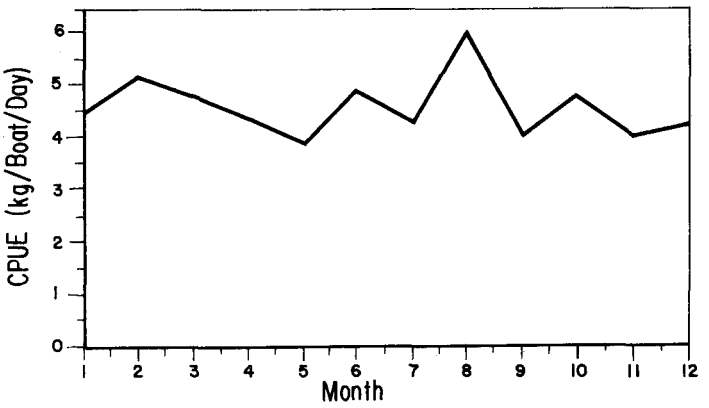

Figure 11 : Monthly CPUE for Penaeus merguiensis from trammel nets

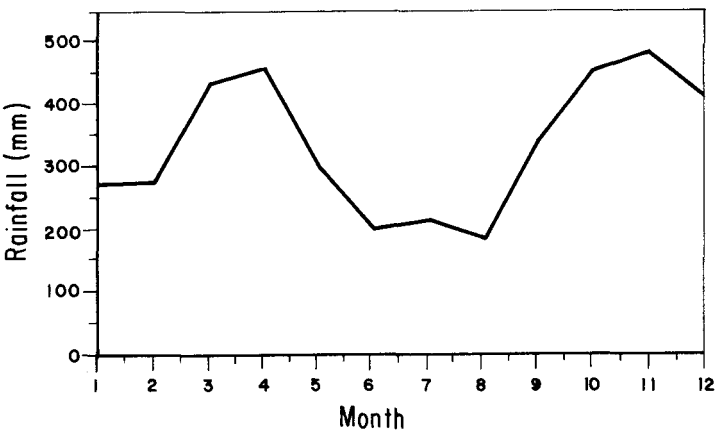

Figure 12 : Average monthly rainfall for the Larut-Matang District (1970-1986)

ANNEX X

NATIONAL RESEARCH REPORT

PAPUA NEW GUINEA

1. INTRODUCTION

Papua New Guinea (PNG) exports about 1,000 tonnes of prawns worth up to K10 million a year. The main commercial prawn grounds occur in the Gulf of Papua, with a small ground located in Orangerie Bay. Daru in the Western Province has an artisanal prawn fishery. In 1989, there is a possibility of opening up a commercial prawn fishery in the PNG side of the Torres Strait Protected Zone between Australia and PNG.

2. DESCRIPTION OF STUDY SITE

Physical Environment

The study site selected for PREP is the Gulf of Papua (Fig. 1). The trawling ground runs parallel to the coast from Fly River in the west to Iokea in the east, and from 5 metres to 40 metres depth. The area is influenced by a number of major river systems entering it, carrying fresh water and sediments from the highlands interior. Plumes of sediments extend up to 5 miles seaward from the river mouths. On the coast is a large area of mangroves extending along most of the coast. Offshore surface water temperature ranged from 26^{o} - 27^{o} (June to September) to 29^{o} - 31^{o} (November to April). No systematic monitoring of the salinity profile has been performed. Currents were studied between 1979 and 1981 in relation to the lobster (Panulirus ornatus) migration and the abundance of penaeid prawns. The bottom sediment consists of silt and mud. Large debris resulting from run off from mangrove forests and rainforest is also present.

The fishery

The fishery in the Gulf of Papua has been in operation since 1969 although reliable catch and effort data have only been collected since 1977. The annual harvest is between 1,000 tonnes and 1,200 tonnes of which banana prawns (P. merguiensis and P. indicus) constitute between 50% and 60%.

The fishery is basically an export fishery in which the product is processed and packed at sea. The catch is separated and packed into four (4) species groups (banana, tiger, endeavour and other). Banana prawns are graded by sizes.

3. TRENDS IN CATCH AND EFFORT

The prawn trawlers which have been operating from 1977 to 1986 were more or less of the same class using the same type and size of trawling gear (twin otter trawls). The effort for this period was measured in number of hours trawled. In 1987, eleven new boats entered the fishery and fished for only part of the year, using a different type

of fishing gear. The total effort for that year, although it should be measured by different units, is still determined by the number of hours trawled. The total annual effort for the last 10 years then increased from 42,108 hours in 1977 to 96,900 hours in 1987 (Fig. 2a). The total annual catch has not dramatically changed during that period although there seems to be a steady decrease in the CPUE (Fig. 2b). As a result of this decrease, a management plan was introduced in 1988 to control the number of trawlers and type of gear used and areas identified as sub-adult habitats were closed to trawling.

4. SEASONAL PATTERNS

The fishery operates all year round with above average catch rates between April and June and below average during the latter part of the year (Fig. 3). This period of high catches coincides with the high rainfall in the northern part of the Gulf of Papua (Fig.4), although no correlation analysis has been done on this. There is no direct explanation on this phenomena as there is no time lag between the rainfall and the high catches. Rainfall may have an effect on the juveniles or sub-adults but because there is no data on these other stages at present nothing can be concluded.

5. SELECTION OF RECRUITMENT INDICES

No information available

6. INTERANNUAL VARIABILITY

No information was presented

7. PRESENT DATA COLLECTION

Gulf of Papua

Since 1977, commercial catch and effort data have been collected from fishing logbooks of prawn trawlers operating in the fishery.

Trawl by trawl records include: area fished, depth, hours trawled, surface temperature and catch of commercial species. The catch was further subdivided into weights (kg) of each commercial size grade. The commercial penaeid prawns, caught are, Penaeus merguiensis, P. monodon, P. semisulcatus, various species of Metapenaeus and coral prawns (P. sculptilis). The data base is processed at the National Computer Centre (NCC). Monthly summaries of catch and effort are calculated. For banana prawns (P. merguiensis), a breakdown of catch and effort by geographic area and size grade is also calculated (Table 1).

This year (1988) a review on data analysis is being undertaken with assistance from the National Marine Fisheries Research Center at Honolulu.

Daru

Data collection is summarized in Table 2.

8. FUTURE RESEARCH

The site selected for the PREP project is the Gulf of Papua (GOP) Prawn fishery, which is of great national importance.

A fisheries project proposal for funding for research in the GOP fishery includes -

Juvenile, sub-adult and adult prawn sampling for annual review at the end of each fiscal year.

The type of assistance required includes technical advice on data analysis, stock production modelling and review of sampling design and sampling techniques for life stages not worked on before.

TABLE 1 DATA COLLECTION - SUMMARY

SITE: GULF OF PAPUA

Species - Penaeus merguiensis, P. monodon, P. semisulcatus, M. ensis, M. eboracensis, M. demani, Parapenaeopsis, sculptilis, T. fulvus

Survey/Sampling	Fishery data	Other Studies
Trawl Monthly (2 weeks) Size Sex Maturity x species	Log Book Shot x shot log Fishing hours x area Catch Sea surface temperature x species group x commercial grade	

TABLE 2 DATA COLLECTION - SUMMARY

SITE: DARU

Species - Penaeus merguiensis, P. monodon, P. canaliculatus, Metapenaeus ensis, M. eboracensis, M. dalli, M. benettae, Parapenaeopsis sculptilis

Survey/Sampling	Fishery data	Other Studies
Pre-survey - Gill net 1",6 ply Not systematic - (22-25m x 1-2m) - Systematic sampling perpendicular to shore Regular Sampling Juveniles - Subadults - Size - Sex - Maturity X Species Lunar month (last 1/4 - new moon) 4 sites x 4-5 subareas x replicates Description/Substance type Sampling Gear - Beach seine (1"x210d/24/x25m length x 2m depth 10 standard nets)	Gill nets Landing sites - Daily records - Area fished Commercial data	Rainfall Temperature Salinity Turbidity Catchability Tides

Sampling Design: Nested ANOVA with uneven sample size
Data Analysis: Manual

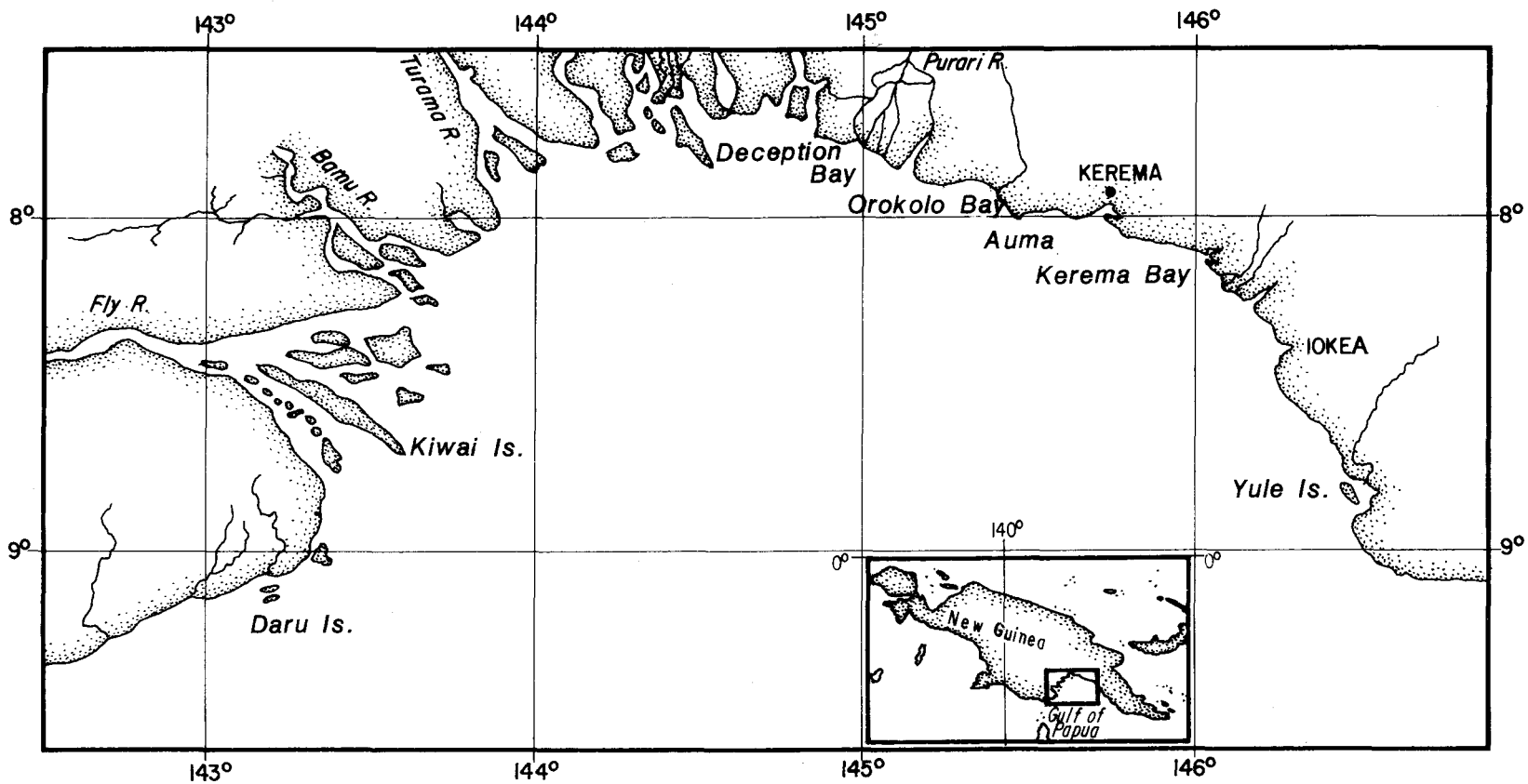

Figure 1 : Map of the Gulf of Papua showing the major rivers.

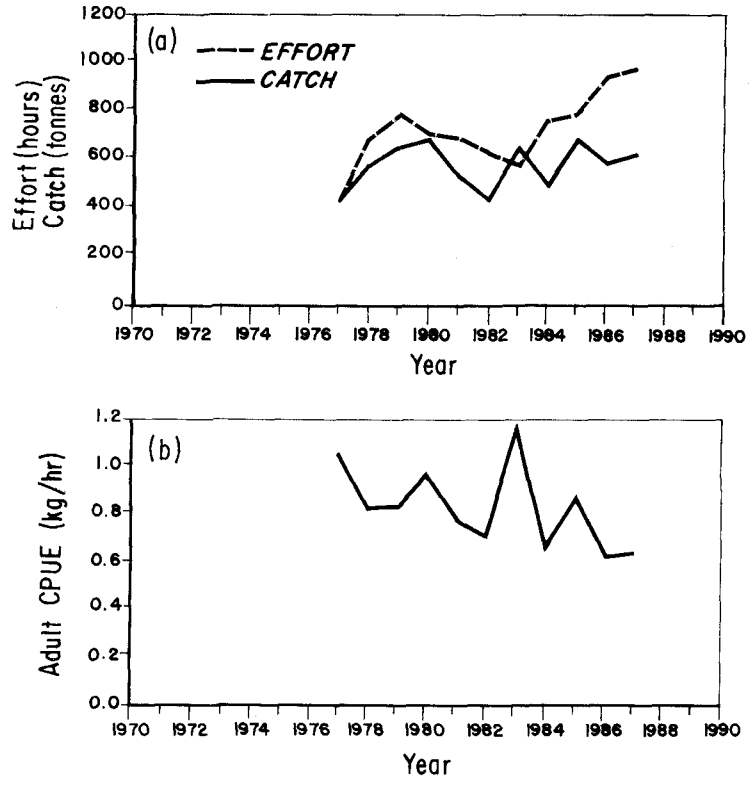

Figure 2a. Annual catch and effort of Penaeus merguiensis in the Gulf of Papua (1977-1987).

2b. Annual CPUE for Penaeus merguiensis (1977-1987) in the Gulf of Papua.

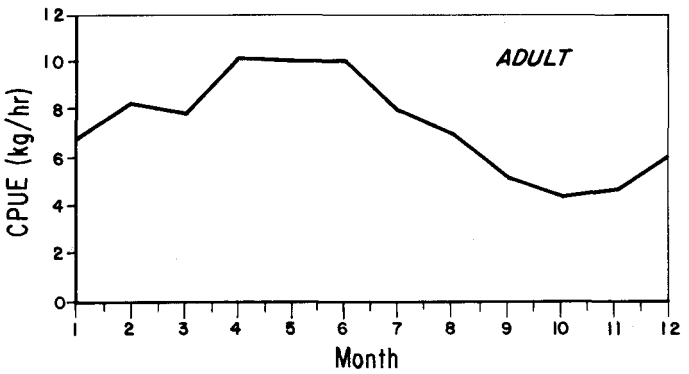

Figure 3 : Monthly CPUE of Penaeus merguiensis averaged over 1977-1986

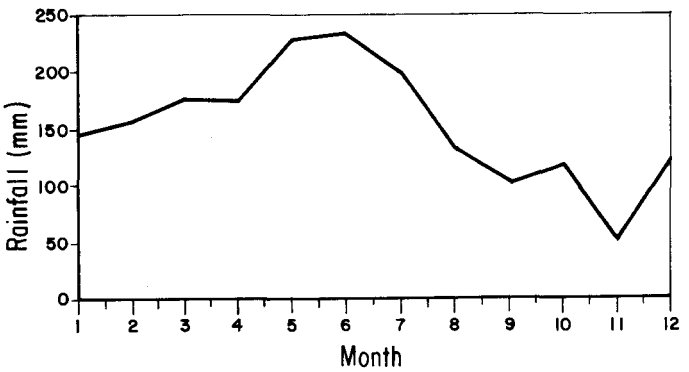

Figure 4 : Monthly average rainfall for the northern Gulf of Papua (1976-1986)

ANNEX XI

NATIONAL RESEARCH REPORT

PHILIPPINES

1. INTRODUCTION

The Philippines are one of the major producers of prawns from the Asia/Pacific region. From 1980 to 1986, prawn exports increased from 2,757 t (P 154m) to 12,108 t (P 2.16 billion). The high demand and price have motivated the fishermen to extensively exploit the resources.

Sorsogon Bay is one of the main prawn producing areas, and several exporting firms are based in the provincial capital of Sorsogon. Since 1972, there has been a controversy concerning the banning of trawl fishing in the Bay. Hydrobiological studies have been conducted in April 1972, November 1975, February 1980 and September 1984, each with different objectives.

It was only in 1985 when a study on the prawn fisheries in Sorsogon Bay was conducted by BFAR that the first attempt to look closely at the prawn resources of the Bay was attempted in order to provide suggestions/options to manage the resources.

2. DESCRIPTION OF THE STUDY AREA

Sorsogon Bay is bounded by longitude 123°50'E and 124°10'E and latitude 12°50'N and 12°59'N (Fig. 1). The Bay has an approximate area of 120 km^2. Its mouth opens to a narrow channel leading to Tieao Pass. It is generally shallow with depths ranging from 0.5 to 9 m (0.25 to 5 fathoms). The deeper portion is at the mouth (10 to 29 m, 5.5 to 16 fathoms: Fig. 2). The various river systems around the Bay drain flood waters during heavy downpours, thus contributing to the enrichment of the water. Mangroves are present along most of the coastline.

Generally, the bottom of the Bay is characterised by very soft mud and accumulated silt. However, there are areas which have sandy bottoms and with some areas with coarser sediments.

The climate of Sorsogon is characterised by very pronounced maximum rainfall from November to January and it is not sheltered from the northern tradewinds or cyclonic storms.

Before November 1976, both small scale commercial and artisanal fisheries existed, but after a presidential mandate was issued in November 1976 the operation of commercial trawl and purse seine within the Bay was banned.

Since then, the fisheries have been artisanal in nature and carried out by numerous fishing boats using various types of gears and operating from numerous landing sites scattered along the coastline. Fishermen use several types of gears, including mini-trawls, gill nets, baby bag nets, hook and line, scoop net with light, air compressors and stationary gears like fish corrals, lift net and fish traps.

The mini-trawls are the most effective fishing gears in catching the invertebrates especially crustaceans, while fishing with the use of air compressor yields mostly bivalves. The catches of mini-trawls were mostly invertebrates, 73% to 87% by weight, of the total catch, while fin fishes were considered as by-catch representing 13% to 27%. Prawns represented 41% to 52% of the catch, followed by crabs, 14% to 26%. Among the prawns, Metapenaeus predominated (24% to 28% of the total catch) while Penaeus merguiensis represented a minimal percentage (0.37% to 0.59%).

3. TRENDS IN CATCH AND EFFORT

For the whole of the Philippines, white prawn landings decreased markedly from 1976 to 1981 and then fluctuated around the mean of 4,000 t. The CPUE also reflects this trend in catches with a dramatic decline up to 1981, followed by a period of fairly high inter-annual variability (Fig. 3a).

The gill net is the most common fishing gear. The CPUE has a marked peak in December but is low for the rest of the year (Fig. 3b). Generally the catch was mainly large size Penaeus merguiensis and most were mature.

Fish corrals abound in the Bay. CPUE was highest during May and decreased abruptly in the succeeding months (Fig. 4a).

Mini-trawl CPUE was observed to have almost constant values from July to November with an abrupt increase in December (Fig. 4b).

The above data are from a two year statistics data (with raising factor). Catches are in metric tonnes and CPUE is catch per boat day.

4. SEASONAL PATTERNS

Two peaks of spawning were observed, July to October and January to February (Fig. 5a). No data on the different life stages of P. merguiensis were available so only data on adults were presented. These data were taken from mini-trawl surveys for a period of 2 years. CPUE is log per hour, the trend in Fig. 5b shows high values of CPUE during the NE Monsoon (October-January). The decrease in December may be due to inadequate data. The trend of catches (Fig. 5b) closely followed the rainfall pattern (Fig. 6). The seasonal pattern of rainfall showed one peak (November). The secondary peak observed in July may be due to the fact that storms frequently occur during that time of the year. Catches may be associated with the amount of rainfall but other factors must be considered.

5. SELECTION OF RECRUITMENT INDICES

High CPUE in P. merguiensis from survey data was observed from October up to November, followed by a low value decrease in December and the highest values in January. The seasonal trend of catches followed the rainfall pattern.

6. INTERANNUAL VARIABILITY

No data on interannual variability are available.

7. PRESENT DATA COLLECTION

7.1 Survey

Regular monthly surveys were conducted over a two-year period using a minitrawler. The length of the boat is 7.5 m and powered by a 16 h.p. gasoline engine. The length of the net is 4.5m with a mesh size of 2 cm stretched in both the net body and the cod end. Trawling was conducted at night. Data collected included: catch composition per haul (kg), actual fishing time and area swept. Usually there are three to four hauls, each with one hour dragging time.

Prawns were identified by reference to the FAO Species Identification Sheets and to Motoh and Buri. Carapace length, sex and maturity were determined. If a large volume of penaeid species was present, one kilogram of that species was randomly taken for biological analyses.

7.2 Fisheries data

Regular monthly samplings at the landing site were undertaken, recording the landed catch of the different fishing gears. Species composition of weight per species in kg was estimated. Generally, five fishing boats were sampled, or if numerous boats went fishing the records of the four prawn dealers were copied. The monthly catch was computed as the average catch (kg) multiplied by numbers of boats that went fishing multiplied by 30 days. Only one landing site exists for the mini-trawl fisheries.

Length measurements, sex, and maturity stage determination were also undertaken.

7.3 Other studies

Diet of prawns - Samples were taken randomly from surveys/fisheries. Only 2 males and 2 females were examined per species in the monthly samples, and their carapace length, sex and maturity were recorded. Guts were examined under the microscope recording the species and number of food items present in the gut.

Parasites - All parasitized prawns from the survey and from fishermen's catch were collected. Carapace length, sex and maturity were determined. The location (side of the carapace) of the parasite was also recorded.

8. FUTURE RESEARCH

8.1 The Philippines intend to carry out a prawn recruitment project through an inter-agency and multi-disciplinary approach following the objectives of PREP in terms of obtaining a better understanding of the effects of fishing and environmental factors on the recruitment of prawns. The emphasis will be on Penaeus merguiensis. However, P. semisulcatus will also be considered.

This national project will be implemented as part of a total programme on assessment of prawns.

In regard to site selection, the Philippines are still considering the question. The various agencies and universities to be involved will be consulted as to the final selection of the site.

8.2 Some level of expertise and manpower capability is available in the Philippines that can be tapped upon as contribution to PREP. Hosting a workshop is also a possibility.

For the Philippines, to be able to carry out its prawn project, it would require assistance in the form of (i) training on data analysis, modelling and larval identification (ii) acquisition of appropriate private software and hardware and (iii) a short term technical assistance on sampling design and collection of data.

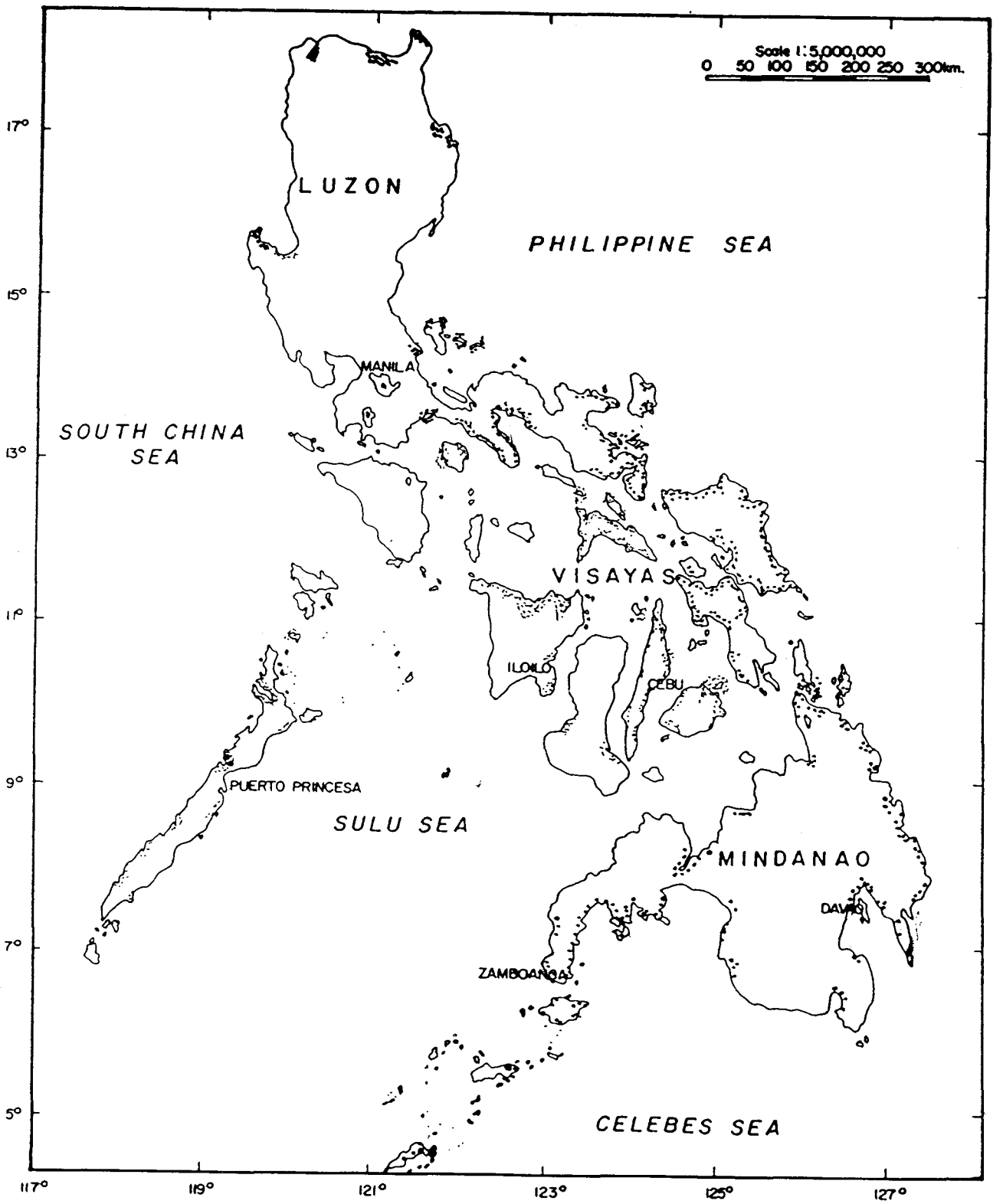

Figure 1 : Map of the Philippines showing location of Sorsogon Bay. Mangrove areas are stippled.

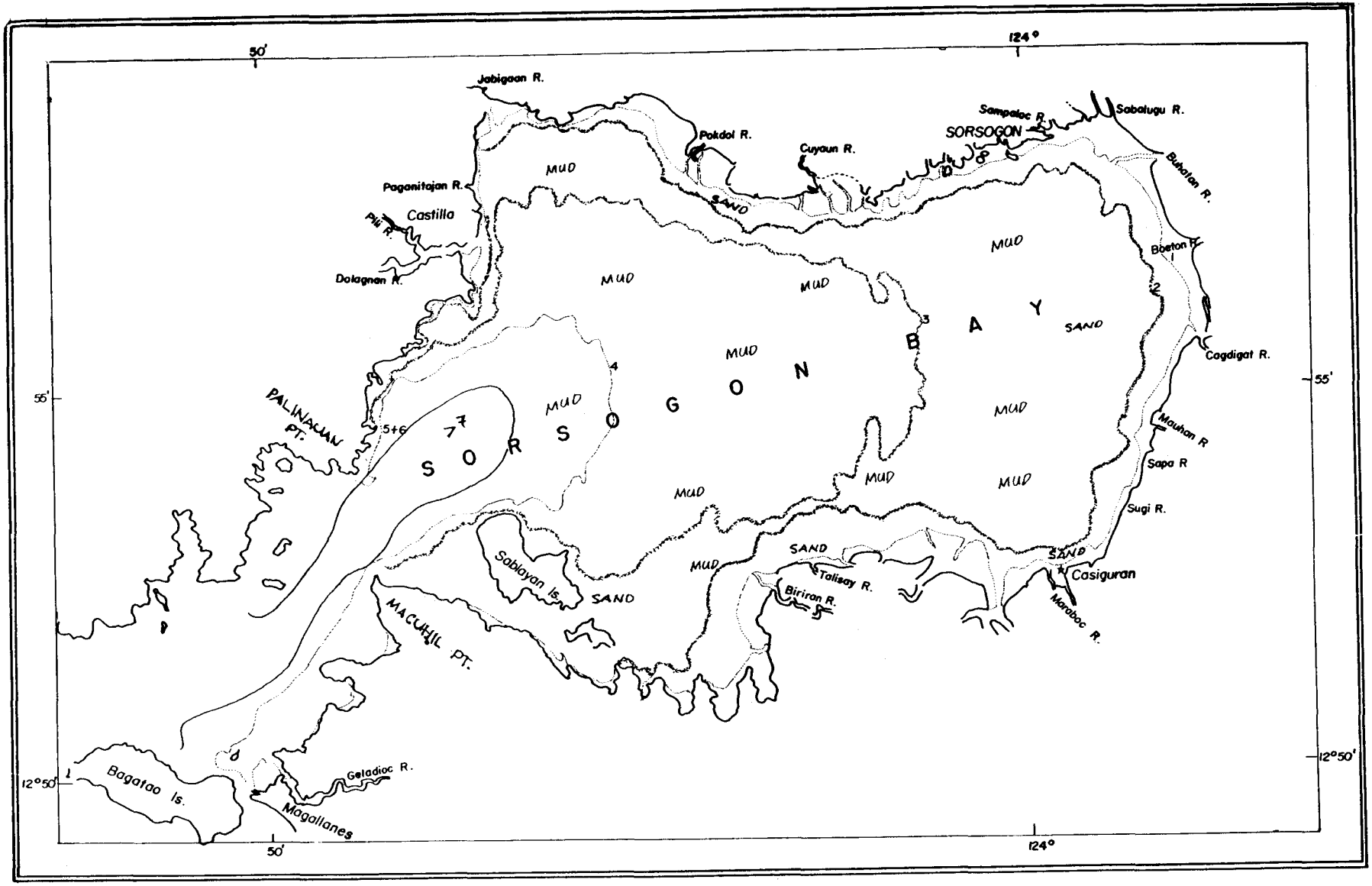

Figure 2 : Sorsogon Bay: substrates and major rivers

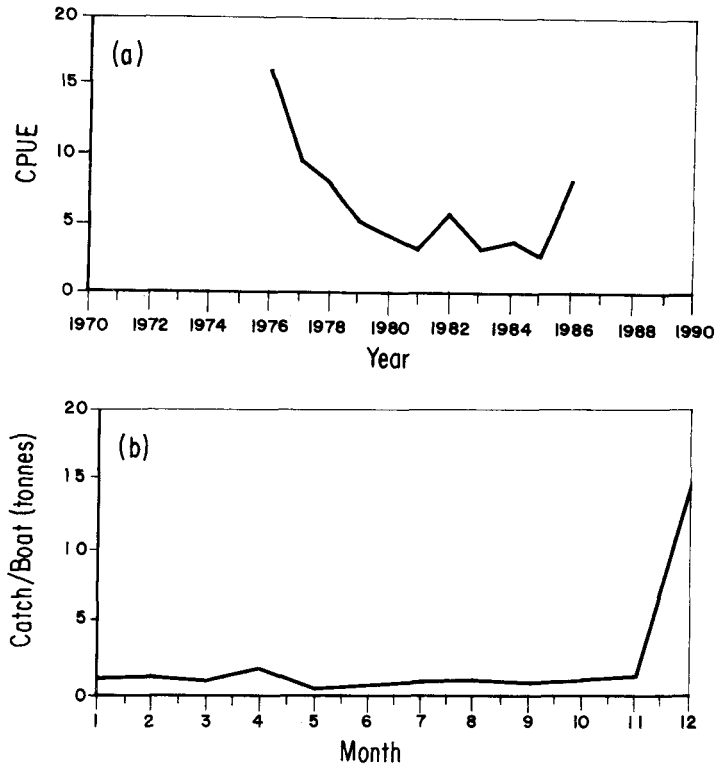

Figure 3a. Annual CPUE of white prawns in the Philippines.

3b. Seasonal CPUE of gill net catches of Penaeus merguiensis in Sorsogon Bay

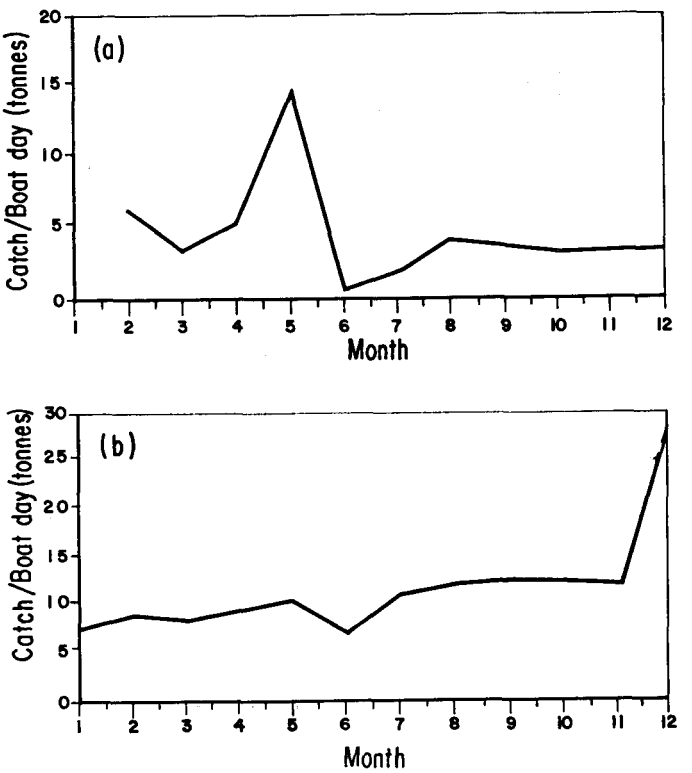

Figure 4a. Seasonal CPUE of fish corral catches of Penaeus merguiensis in Sorsogon Bay.

4b. Seasonal CPUE of mini-trawl catches Penaeus merguiensis in Sorsogon Bay.

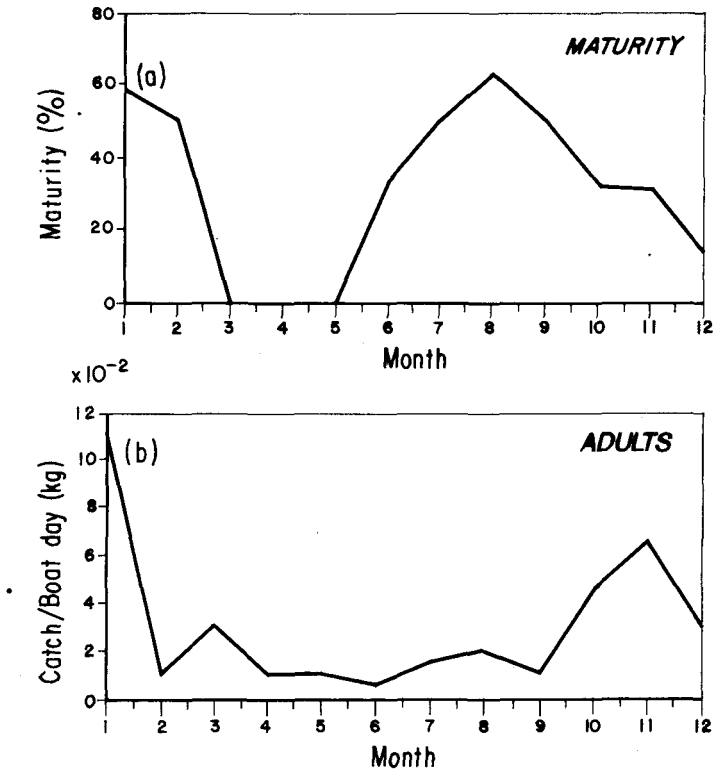

Figure 5. Seasonal pattern of Penaeus merguiensis:

a. Spawning (percent maturity)

b. Adult abundance

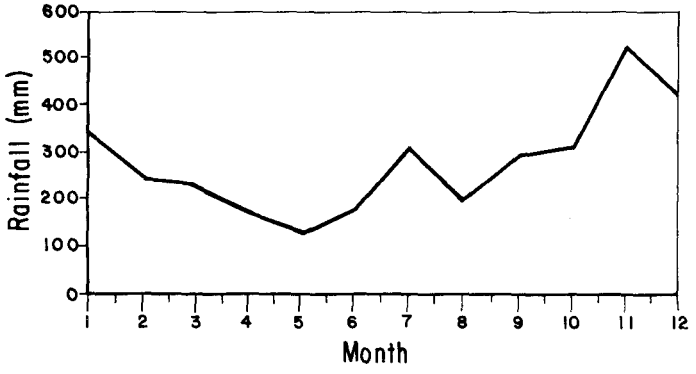

Figure 6 : Average monthly rainfall in the Sorsogon Bay region

ANNEX XII

NATIONAL RESEARCH REPORT

THAILAND

1. INTRODUCTION

Prawns are the main component of the country's export products, especially frozen and canned products with a value of $180 million or 27% of total exports of marine product of Thailand in 1985.

Among the large prawn landings in Thai waters, banana prawn, Penaeus merguiensis is the most important species (40% of the total of large prawns). The catches increased and reached a peak of 16,291 t in 1981, then declined thereafter to 8362 t in 1985. In contrast, the production of prawn from farming increased steadily up to 10,397 t in 1985, which surpassed the amount landed in that year.

The decline of prawn production in the Gulf of Thailand was caused by overfishing of both adult and juvenile stages. The prawn was exploited by coastal fisheries of which 72% came from trammel netting, 15% from otter board trawling, 4% from push netting, 4% from set bag netting and 5% from the use of other fishing gear.

2. DESCRIPTION OF STUDY AREA

Ban Don Bay is located at 9°N in the western Gulf of Thailand and is considered to be one of the most productive prawn fishing grounds (Fig. 1). Ban Don Bay covers an area of about 20,000 km^2 and is the site of the commercial trammel-net and otter-trawl fisheries.

The nursery ground studied was the Donsak River, which has a length of 10 km. There are many prawn farms of traditional type along both sides of the river. The river provides enough wild postlarvae of banana prawn to seed the farms. Mangrove trees are sparse along the side of the river.

3. TRENDS IN CATCHES AND EFFORTS

3.1 History of the fisheries

In the early days, prawn fisheries in the Gulf of Thailand were generally on a small scale, being confined to the coastal waters and carried out mostly by unpowered boats using traditional gear and methods. Those gears were set bag nets, scoop nets, cast nets, push nets and gill nets. In 1961, the Department of Fisheries encouraged the fishermen to invest in the otter trawl fishery which had proved tc be suitable for the Gulf of Thailand and became popular a few years later. The number of trawl units rapidly increased. Besides the trawls, the use of push net and trammel nets also rapidly increased.

3.2 Catch - Effort

The annual prawn catch and effort data from the otter board trawl in the western coast of the Gulf of Thailand fluctuated between 1971 and 1986 reaching a peak in 1981, then rapidly decreasing (Fig. 2). The fishing effort from 1981 increased slightly.

The statistical survey data from the Statistical Section of the Department of Fisheries were used to standardise the catch and effort data. The otter trawl <18mlong has been used as the standard gear for calculating the fishing effort in trawling hours.

4. SEASONAL PATTERN

4.1 Life History stages

Banana prawns in Ban Don Bay appeared to spawn throughout the year with two main peaks, one in March and one in September. Peaks in the number of protozoea and mysis larvae also occurred during these months (Fig. 3a).

Postlarvae move into the mouth of the Donsak River from February to September with a prominent peak in September (Fig. 3b). This peak was not reflected in the juvenile prawns which were found in greatest numbers in May, July and September (Fig.3c).

The prawns moved from the nursery area to the sea and became available as subadults to the small scale fisheries and as adults to the commercial fisheries during the latter part of the year (Fig. 3d).

4.2 Environment

The southern part of Thailand is dominated by the seasonal alternation of the two winds of the NE and SW monsoon. They bring rain to this part from May to the end of the year with the highest peak in November (Fig. 4).

4.3 Fishing

Trammel net fisheries exploited adult banana prawn throughout the year, having good catches per hour from August to the end of the year.

5. SELECTION OF RECRUITMENT INDICES

Monthly CPUE from the push net and trammel net surveys for P. merguiensis in Ban Don Bay showed a peak from September until January, which were apparently related to recruitment of small prawns into the fishery from April.

6. INTERANNUAL VARIABILITY

The average rainfall in the study area ranged from 1,373 to 2,308 mm between 1971 and 1987. It reached a peak of 2,308 and 2,040 mm in 1975 and 1986 respectively.

7. PRESENT DATA COLLECTION

Two kinds of fishing nets were used in the offshore sampling for larval and postlarval prawns (CL<3mm) during the day each month. A 1 x 1.5 m rectangular fixed frame beam trawl, which was fitted with 1 mm mesh net, was towed along the bottom. At the surface, a larval net with a diameter of 1m fitted with a net 3m long and a mesh size of 1 mm was used. Both were towed for 10 minutes for 6 stations perpendicular to the coastline at the mouth of the Donsak River.

Both larval nets and beam trawls were used in the river sampling for postlarvae and juveniles (CL 3-12mm) during night hours each week following the lunar phase. The towing period was reduced to 5 minutes. Surface water temperature and salinity were recorded directly using a portable conductivity salinometer.

A push net with a mouth width of 14 m and a cod end mesh size of 7 mm covered with 1.5 mm mesh at the end was used to collect juvenile and subadult prawns (CL 13-23 mm). This was used both in the river and inshore area up to a depth of 5m (about 3 km from the shore line).

All samples were sorted into species and measured (size of CL) to the nearest 0.1mm using eyepiece micrometer for postlarvae and 1 mm for juveniles, subadults and adults. A study on the parasites of prawns has also been carried out.

Adult prawn samples (CL>23mm) were obtained from both trawl surveys and commercial fisheries landing places each month (otter trawl, trammel net and push net). Prawns were then sexed and the maturity stage of the gonads was determined. Prawns with TL longer than 13 cm were considered to be mature. An interview system is used to collect catch and effort information and TL measurements are also taken.

At present, Ban Don Bay is intensively studied for water quality, heavy metals and pesticides, oceanographic data, biological parameters, aquaculture (oyster, clam, prawn, etc.), both hatchery and grow out system. Most of the research is carried out by the Department of Fisheries, Department of Meteorology, Department of Oceanography (NAVY) and Chulalongkorn University.

8. FUTURE RESEARCH

The future research programme of prawn resources in Thailand involves collecting information on both the biology and population dynamics which will be used for applying appropriate fisheries management. Studies are planned on:

1. Spawning season and spawning ground.
2. Nursery ground; distribution and seasonal abundance of larvae, postlarvae, juveniles, subadults and effects of environment.
3. Population structure; recruitment.
4. Stock assessment; optimum fishing effort.

To carry out this research sufficient tools and funds are needed.

1. A mini computer or IBM PS60 or PS80 model.
2. Statistical analysis package, such as SPSS, SAS and SYSTAT.
3. Technical assistance and training programme on sampling techniques and data analysis.

TABLE 1 DATA COLLECTION - SUMMARY

The target species for the study site comprise 7 large sized species -
Penaeus merguiensis, P. semisulcatus, P. latisulcatus, P. monodon, Metapenaeus affinis, M. ensis and M. intermedius, and also 1 species of small sized prawn Parapenaeopsis hungerfordi.
The data were collected as follows:

Survey/Sampling	Fishery Data	Other Studies
Larvae - Surface Plankton - (Plankton net 1mm) - Benthic plankton - (beam trawl 1mm) - Monthly transects - Unit - No./m^3	Subadult & Adult Trawl, Trammel net and Push net Monthly landing site - Catch & Effort (Skipper interview) - Size - Sex - Maturity	Oceanographic Data Water Quality Heavy Metals Pesticides Hatchery Maturation Parasite
Juveniles - Beam trawl 1 mm Push net (cover net 1.5mm) - Weekly in estuarine - Unit - no/m^3 - Size measurement & mm		
Subadults - Push net 7 mm - Weekly in estuary - Unit & gm/hr - Size measurement & mm		
Maturity - - Mexican Trawl (2.5 cm) - Trammel Net - Monthly offshore		
Environment - Salinity - Temperature		

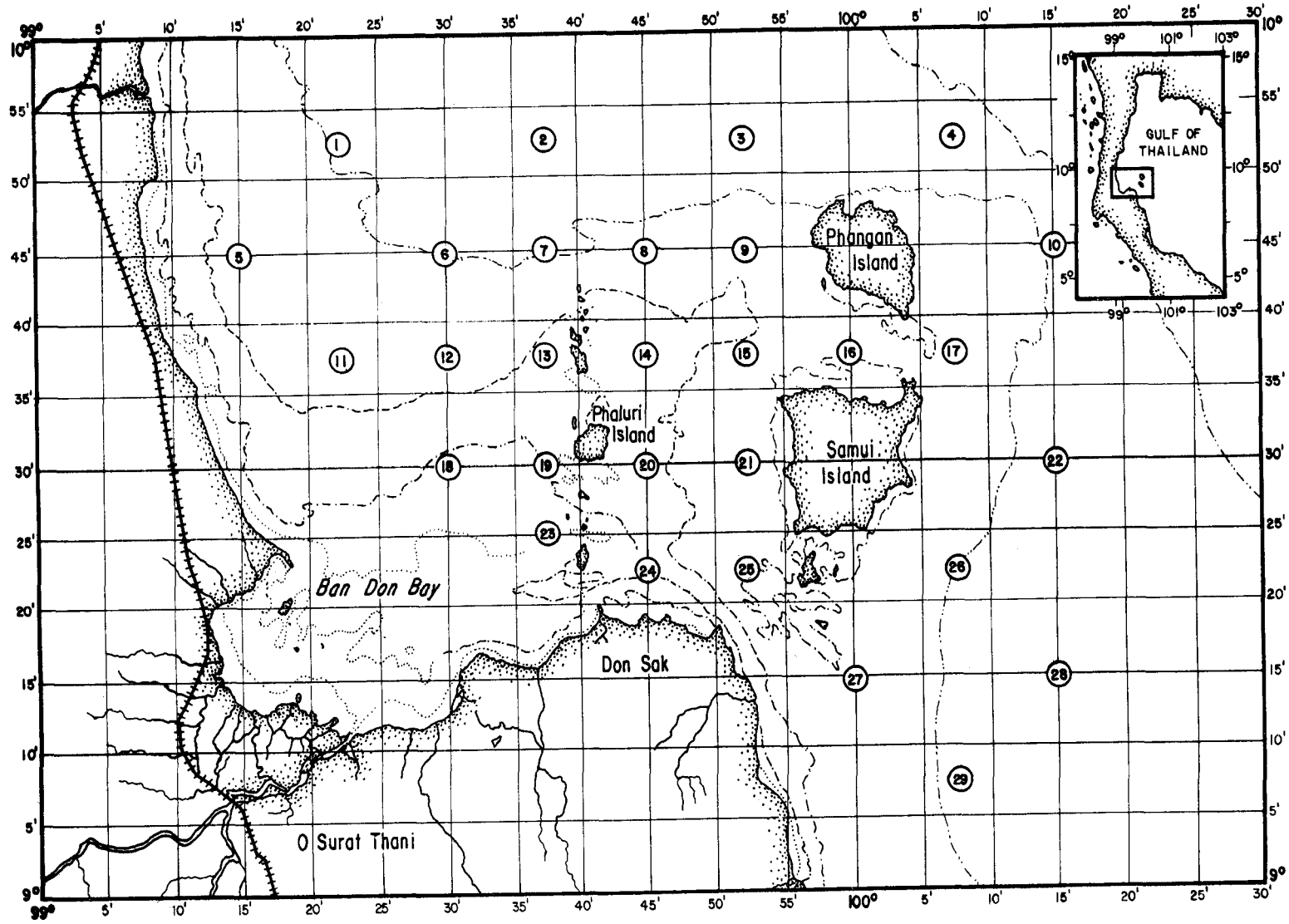

Figure 1 : Map of station locations in Ban Don Bay, western Gulf of Thailand

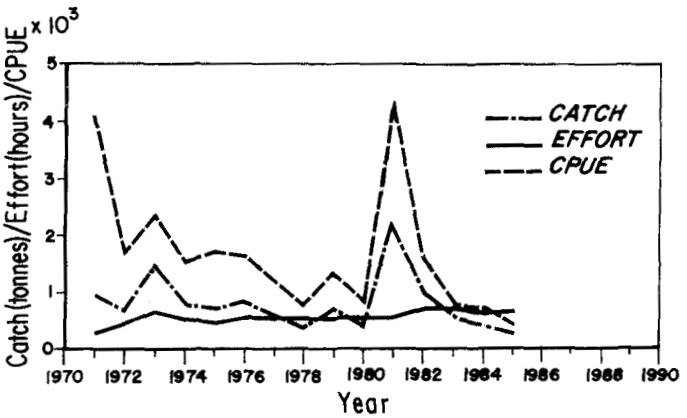

Figure 2 : Annual catch, effort and CPUE for Penaeus merguiensis in the west coast of the Gulf of Thailand (otter trawls <18 m).

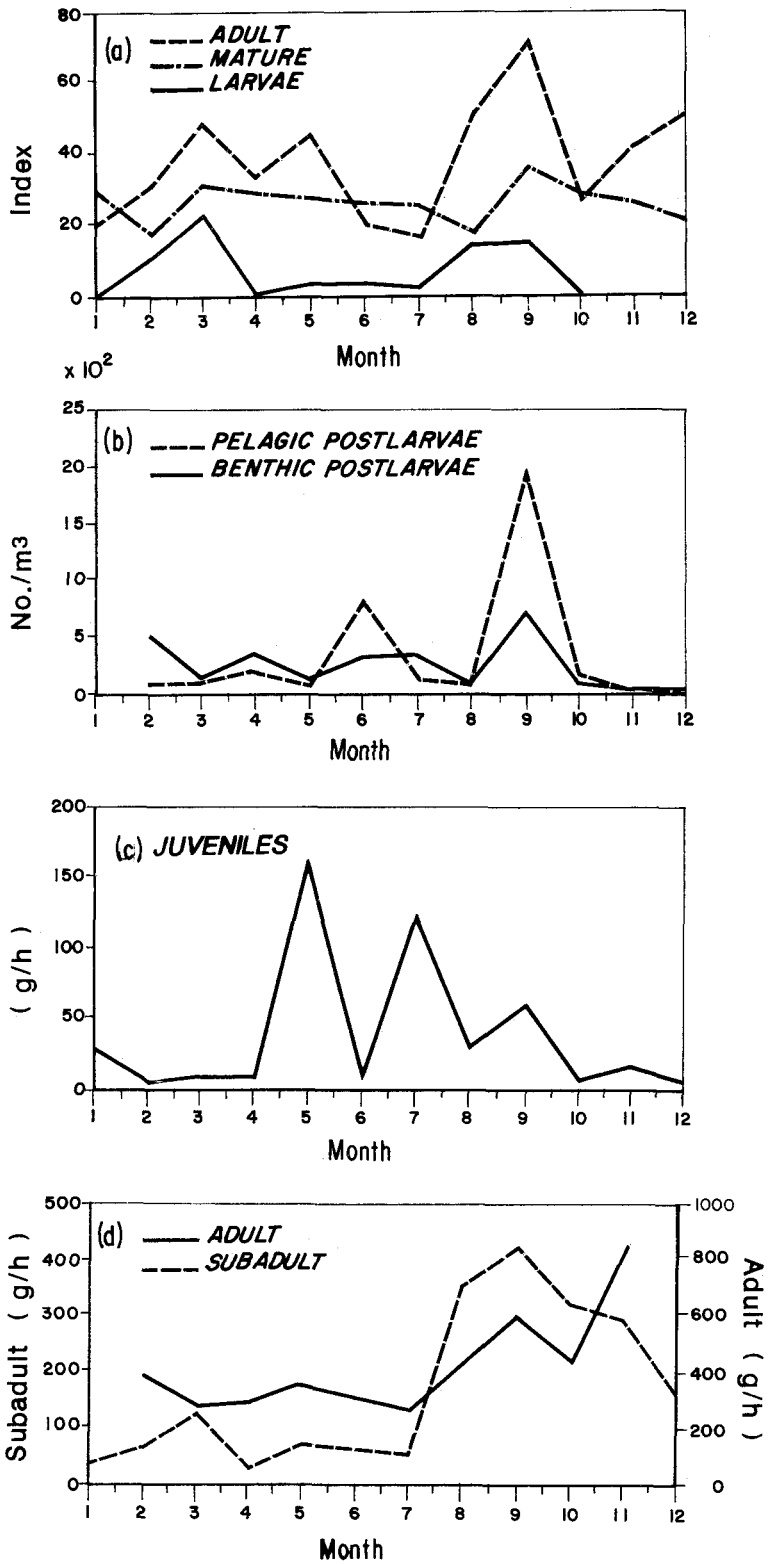

Figure 3 : Seasonal patterns of Penaeus merguiensis:
a. Adults, spawning (percent mature) and larvae
b. Pelagic and benthic postlarvae
c. Juveniles
d. Subadults and adults

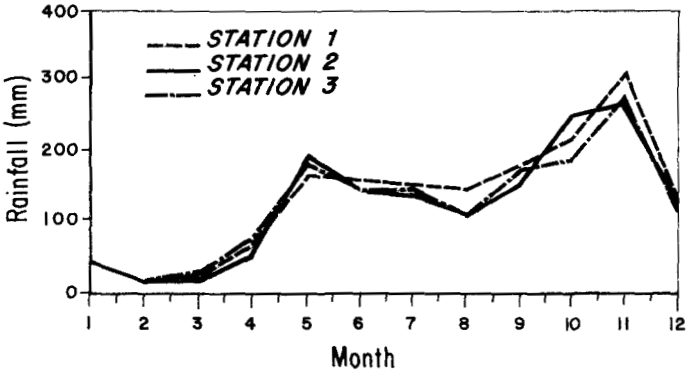

Figure 4 : Average monthly rainfall for the western Gulf of Thailand(three stations)

No.	Title	Publishing Body	Languages
32 Suppl.	Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife 12-17 December 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English French Spanish
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36	IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
36 Suppl.	Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37	IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
37 Suppl.	Papers submitted to the IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
40 Suppl.	IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications *Submitted Papers* Sidney, B.C., Canada, 29-31 July 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
42	IOC/UNEP Intercalibration Workshop on Dissolved/Dispersed Hydrocarbons in Seawater Bermuda, USA, 3-14 December 1984 (in press)	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
44	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English (out of stock) Spanish
44 Suppl.	IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities - *Submitted Papers* Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
45	IOCARIBE Workshop on Physical Oceanography and Climate Cartagena, Colombia, 19-22 August 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
46	Reunión de Trabajo para Desarrollo del Programa «Ciencia Oceanica en Relación a los Recursos No vivos en la Región del Atlantico Sudoccidental Porto Alegre, Brazil 7-11 de Abril de 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	Spanish
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence Townsville, 1-6 December 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on "Ocean Science in Relation to Non-Living Resources (OSNLR)"	IOC, Unesco Place de Fontenoy 75700 Paris, France	English Spanish
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on "El Niño" Guyaquil, Ecuador, 27-31 October 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
50	CCAMLR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR) Paris, France, 2-6 June 1987	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations, Lae, Papua-New Guinea, 1-8 October 1987	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
52	SCOR-IOC-Unesco Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere Paris, 6-10 May 1985	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
53	IOC Workshop on the Biological Effects of Pollutants Oslo, 11-29 August 1986	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
54	Workshop on Sea-level Measurements in Hostile Conditions Bidston, UK, 28-31 March 1988	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
55	IBCCA Workshop on Data Sources and Compilation Boulder, Colorado, 18-19 July 1988	IOC, Unesco Place de Fontenoy 75700 Paris, France	English
56	IOC/FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP) Cleveland, Australia, 24-30 July 1988	IOC, Unesco Place de Fontenoy 75700 Paris, France	English