Pauly, D., F.C. Gayanilo Jr. and G. Silvestre. 1997. A low-level geographicinformation system forcoastal zone management, with applications to Brunei Darussalam. Part 1: Theconcept and its design elements. *Naga, the ICLARM Quarterly* 20 (2): 41-45.

A Low-level Geographic Information System for Coastal Zone Management, with Applications to Brunei Darussalam: Part I: The Concept and its Design Elements*

D. PAULY, F.C. GAYANILO, JR. and G. SILVESTRE

Abstract

This contribution is the first part of a four-part series documenting the development of B:RUN, a software program which reads data from common spreadsheets and presents them as low-resolution maps of states and processes. The program emerged from a need which arose during a project in Brunei Darussalam for a low-level approach for researchers to communicate their findings as efficiently and expeditiously as possible. Part I provides an overview of the concept and design elements of B:RUN. Part II will highlight results of the economics component of the program, evaluating different fishing scenarios with changes in [illegible] and fleet operating costs. Environmental aspects will be presented in Part III in the form of vector maps. Part IV will summarize the implications of B:RUN results to coastal and fishery resources management in Brunei Darussalam and show how this approach can be adapted to other countries and used as a teaching and training tool. The following three parts will be published in future editions of *Naga*. The program is available through ICLARM.

Introduction

One major problem facing researchers on natural resources is the communication of their findings. If researchers do not make specific efforts to bridge the communication gap, their results will be ignored by decisionmakers, often with disastrous consequences for the resources. Research itself will also be affected by this lack of communication with eventual lack of funding and by lack of subsequent application.

Effective and successful research communication can encourage natural resources scientists to identify key elements that must be taken into account when considering management options. Research communication forces scientists to bridge the chasm between *holism*, the research mode appropriate when dealing with multidimensional complex systems, and *reductionism*, the mode ultimately required for management interventions (Pauly 1994).

The timeliness of suggestions from researchers is also extremely important. Given the conceptual and computer tools presently available, highly complex, realistic simulation of any system can be developed, but this costs time. Unfortunately, the resulting advice will often come too late.

Well-communicated research advice must therefore: (1) break the conceptual and other barriers separating scientists and decisionmakers; (2) present those key processes and management options that are essential, even if the system under study is highly complex and affected by a myriad of interlinked processes; and (3) be made available at the right time *before* the resource system in question is irreparably damaged, or before investment or other decisions are taken that would lead to such damage.

An approach is presented in this paper for dealing with these research communication needs in the context of coastal resources, focusing specifically on tropical coastal fisheries management.

The Project Leading to B:RUN

From 1986 to 1993, ICLARM executed a USAID-funded Coastal Resources Management Project (CRMP) with a site in each of the six ASEAN countries. The site in Brunei Darussalam included the coastal waters of the entire country (see Silvestre et al. 1992 and Fig. 1).

As a subcomponent of the project, Hj. Abdul Halidi bin Mohd. Salleh, from the Brunei Department of Fisheries spent March and April 1987 at ICLARM Headquarters. Under the guidance of D. Pauly, he analyzed data from a monitoring survey conducted annually on two selected grid squares since 1982, when the last comprehensive trawl survey off Brunei Darussalam had been carried out (Beales 1982). One result (Fig. 2) seemed to indicate that the demersal stocks were rapidly declining. A decision was made to conduct a new comprehensive trawl survey of Brunei coastal waters (Box 1) within the framework of the CRMP.

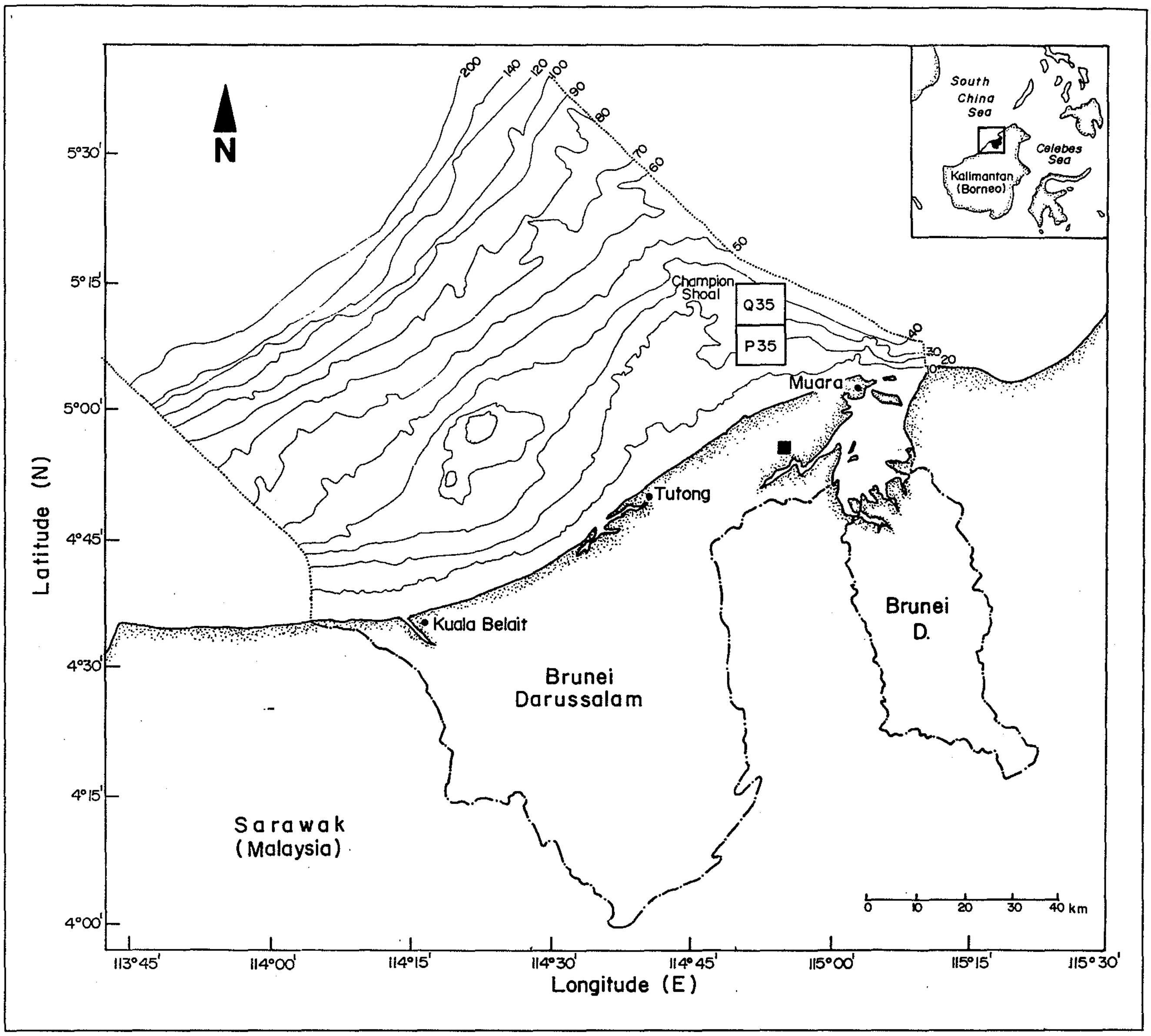

Fig. 1. Map of Brunei Darussalam showing locations mentioned in the text.

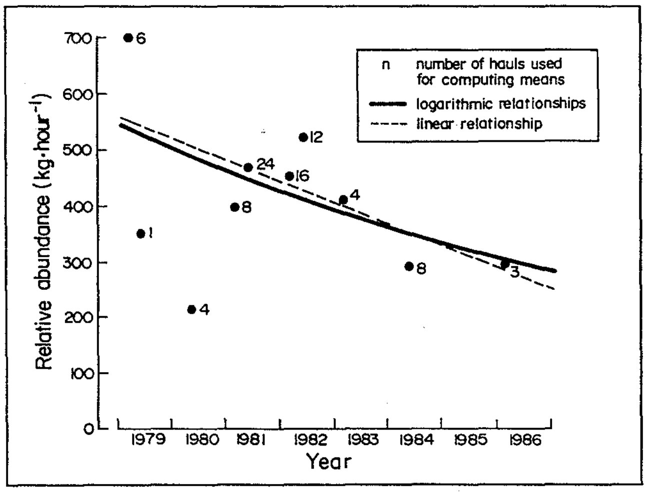

Fig. 2. Trend in catch/effort (abundance) off Muara, Brunei Darussalam (squares Q35 and P35 in Fig. 1) from 1979 to 1986. The trend lines have slopes significantly different from zero if fitted using the number of hauls involved in computing means (black dots) as weighting factors.

This survey, led by G. Silvestre, found that, in fact, the fishery resources as a whole had not declined, but only the resources closest to Muara (the home port of the then eight-vessel Brunei Darussalam trawl fleet), which included the two grid squares (Q35 and P35) that had been monitored (Fig. 1).

However, the new survey raised more questions. Could the relatively high fish biomass off Brunei Darussalam be used to achieve the country's goal of substituting (or reducing) fish imports? How many additional trawlers would be required to exploit this resource? What were the

Box 1. The 1989-1990 Department of Fisheries (Brunei Darussalam)/ ICLARM trawl survey.

A trawl survey (random-stratified) was conducted in the coastal waters of Brunei Darussalam from July 1989 to June 1990 by staff of the Brunei Department of Fisheries (DOF) and ICLARM. The survey area covered roughly 4 600 km² from 10-100 m depth - excluding "restricted areas" due to the presence of oil industry structures, navigation cautionary areas, and coral/hard grounds. The survey area was stratified into 10-m depth intervals and the trawl stations distributed in a "systematic-random" fashion among the various depth strata. The trawl stations were fished during daylight hours on a monthly basis during the course of the survey period using the DOF's *K/P Lumba-Lumba* (15.2 m LOA, 287 hp) and a "Boris Goshawk" trawl (9.1 m effective headrope, 3.5 cm cod-end mesh size). At each of the trawl stations, the trawl was dragged for half an hour at 3 knots. The catch at each station was sorted and weighed to species level whenever possible, and the length composition of the more abundant and commercially important species was taken.

A total of 143 valid trawl hauls were conducted off Brunei Darussalam during the course of the trawl survey. The demersal fauna is highly diverse - with about 400 species belonging to 170 genera and 100 families observed in the catches during the survey. Stock density varies with depth (see Figs. 3 and 4), and is higher in the shallow areas (averaging 11.7 t/km² for 10<50 m depth) compared to the deep grounds (averaging 3.6t/km² for 50-100 m depth). Demersal biomass in the entire survey area is estimated at about 32 200 t dominated by low-value species such as slipmouths (Leiognathidae, 28.1%), goat fishes (Mullidae, 8.0%), sharks/rays (7.6%), threadfin breams (Nemipteridae, 7.6%), and sciaenids (Sciaenidae, 7.1%). Demersal potential yield is estimated to be 11-16 thousand t/yr.

Key results of the trawl survey viewed in the context of the capture fisheries situation in Brunei Darussalam are given in Silvestre and Matdanan (1992). Silvestre et al. (1993), moreover, utilized the results of the trawl survey (and related assessments) to construct a trophic model of the coastal fishery resources of Brunei Darussalam. These indicate the demersal fishery resources to be lightly fished overall. The resources exhibit potential for increased fishing pressure - and the DOF is pursuing a carefully considered, phased expansion of the country's trawl fishery.

-G. Silvestre, M.S. Abdul Halidi and S. Selvanathan

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constraints for the present fleet? Why had it not expanded operations beyond a small area around Muara?

Given the fact that the other Southeast Asian countries with the same type of demersal fish resources have seen their demersal fleet bloom, and then drastically diminish (Pauly 1988, 1994; Pauly and Chua 1988), we suspected economic and/or operational constraints on the trawl fleet in the country. Since it was known that the biomass of Southeast Asian demersal stocks decline rapidly farther away from the coast (Fig. 3), while fishing costs increase mainly due to fuel consumption, it was initially decided to use a geographic information system (GIS) for analyses. The authors soon realized that it would be very time-consuming to digitize the map required and, moreover, since the map would be tied to the availability of a given set of GIS tools, it could not be widely distributed.

A 'low-level' approach was chosen, where the crucial information (demersal fish abundance and sailing distances from ports by 5-nautical mile grid squares) would be stored in spreadsheet format (such as LOTUS 1-2-3), and plotted as low-resolution 'maps' on a high resolution base map (Fig. 4). This approach, programmed by F.C. Gayanilo, Jr., makes it possible for any MS-DOS computer to run the resulting software, free of any copyright restriction (Fig. 5). It also allows easy data entry (via LOTUS 1-2-3) and flexibility in translating the software for use with other coastlines.

Moreover, to communicate the key results of the economic and fleet operational component of the software (details in Part II) more effectively, the program was enhanced with a few high-resolution overlays displaying coral reefs, oil structures and other important features of the Brunei Darussalam coast (details in Part III).

The resulting software is B:RUN, presented in this and three forthcoming contributions, along with the main implications for resources management in Brunei Darussalam.

Simulation of Stock Dynamics and Fleet Operations

Stock dynamics and fleet operations are incorporated in B:RUN through four related components:

(i) grid square-specific surplus production models to express gross returns (assumed proportional to catch in weight) as a parabolic function of fishing effort, express trawl hauls per year;

(ii) fishing grounds, i.e., a group of grid squares near Muara, off Tutong, off Kuala Belait, or offshore;

(iii) grid square-specific fishing costs, composed of variable costs, influenced by sailing distance from either the ports of Muara or Kuala Belait, and of fixed costs;

(iv) A fishing regime determined by (a) a choice of level of effort, determined by the number of hauls per trip and the number of trips per year, and (b) a choice of fishing port.

The surplus production model used was derived from a plot of catch-per-effort vs effort for grid squares in the Muara area, the main area exploited by trawlers at the time. The parabolic production curve thus obtained was extended to other areas (i.e., grid squares) by making maximum sustainable yield (MSY) from such areas directly proportional to the largely unexploited biomass observed there. However, this led to biased results be-

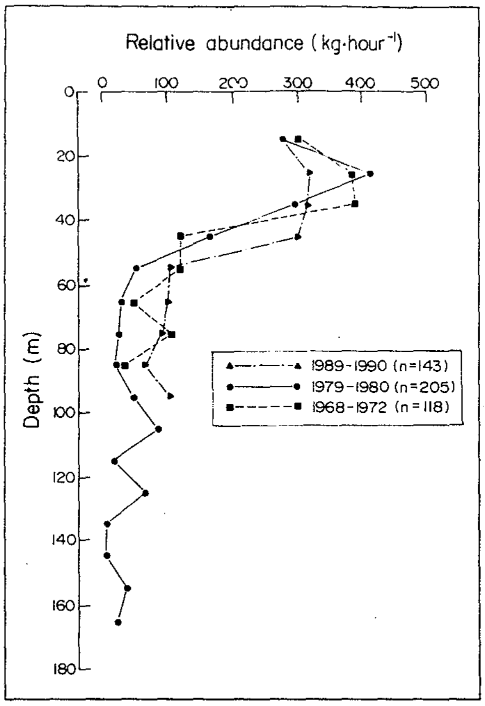

Fig. 3. Relationship between demersal resource abundance (as estimated by research trawlers) and depth off Brunei Darussalam. Note peak at 30 m, typical of Southeast Asian waters.

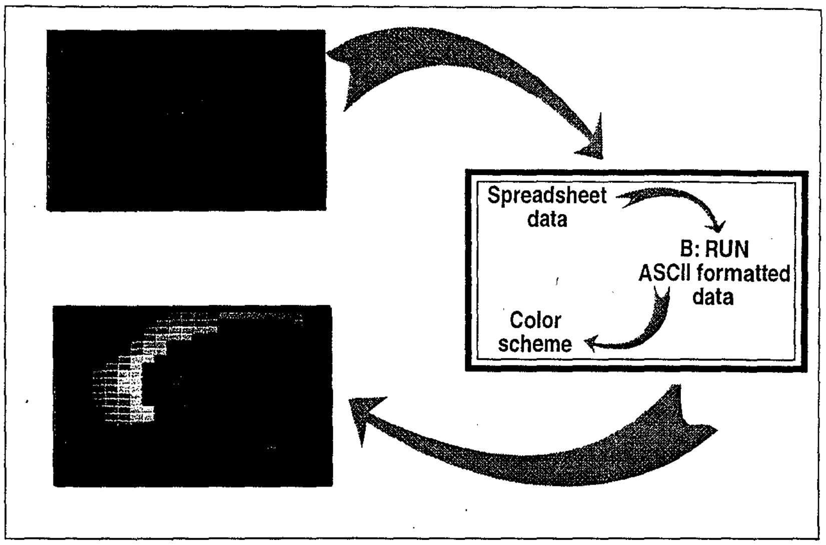

Fig. 4. Screen output (low-resolution) of the mean catch per effort (kg·hour⁻¹) during the 1989-1990 trawl survey. Blue is assigned to the smallest range of values and red to the highest.

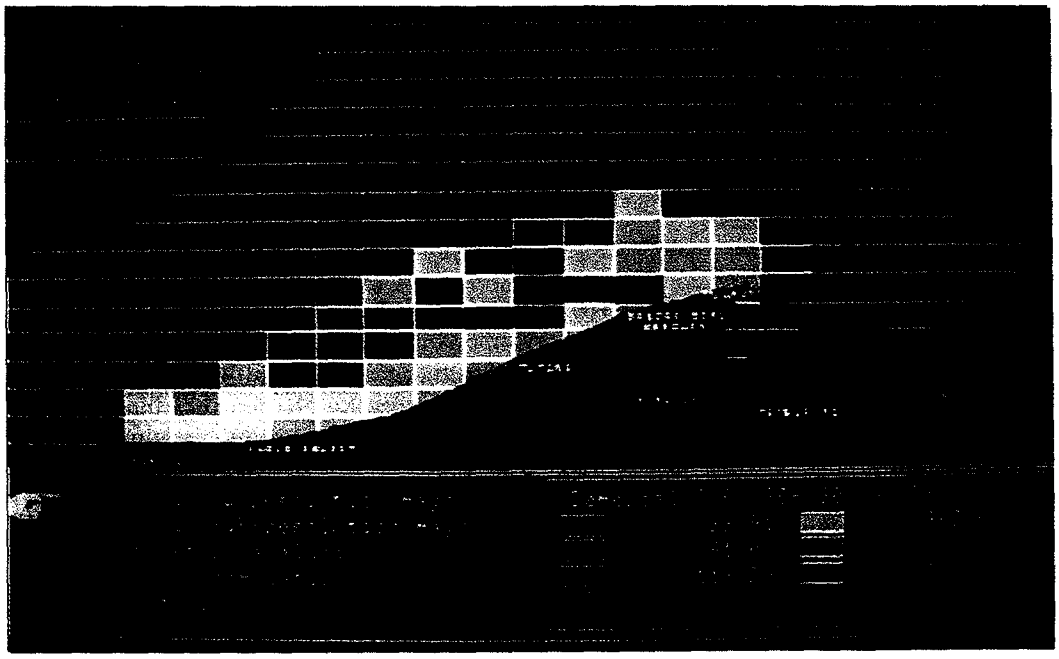

Fig. 5. Structure of B:RUN.

cause the fish in offshore areas tended to be larger and longer-lived, and hence would have relatively lower MSY than the fish in inshore areas; although this bias is negligible compared to the bias caused by not considering multispecies interactions (both technological and biological) and interactions between grid squares.

The initial capital costs, variable costs and fixed costs of Muara-based trawlers (mean length of 19 m, with 175 hp diesel engines and a crew of six) were estimated in May 1990, based on financial data from five out of the eight trawlers operating at the time. These costs, which will be described in Part II of this series, were incorporated as "defaults" in B:RUN.

The fishing regime is determined by effort level and the choice of a home port. Muara is the only fishing port accessible to trawlers in Brunei Darussalam and all trawlers must depart from and return to it. In B:RUN, however, we have allowed Kuala Belait (near the western border of Brunei Darussalam) to be used in the simulations as an alternative port for trawlers. This would enable users to get a feel for the impact of distance on the profitability of a given area (or set of grid squares), and also simulate the impact that dredging of the channel leading to the port of Kuala Belait would have on development of the Brunei trawl fishery.

The result of a given set of parameters can be presented in two forms: (i) as low-resolution map showing areas that are profitable (green), intermediate (yellow) and unprofitable (red) for trawlers, or (ii) a plot of the grid square-specific total costs and revenues vs effort indicating MSY, maximum economic yield (MEY) and open-access equilibrium point (OEP).

Discussion

The implications of B:RUN to coastal and fishery resources management in Brunei Darussalam will be discussed in Part IV.

However, it can already be noted that B:RUN was successful because it presented processes and problems in the form of maps, i.e., using the very spatial dimensions that structure these processes and problems; and it was developed during the lifetime of a project which was addressing major development issues - something which would not have been possible in the case of a complex simulation model.

These two factors satisfied the holistic features of B:RUN but there were compromises. High resolution maps were not used except for a few overlays depicting coral reefs, restricted fishing areas and oil structures. This proved advantageous because we had to rely on the power of simple spreadsheets, available on most personal computers, unlike real, high resolution GIS. There was little time for software development so that details such as simulated "flows" of fish from fished and unfished grid squares (MacCall 1990), which would have made the fleet economics model biologically more accurate, were not added.

Emphasis was given to the economic aspects of the simulation, and particularly to accounting for the cost of reaching offshore areas. It was shown that trawler profitability was greatly affected by the cost of reaching offshore areas, and the generally low biomass found there. This impact did not change even with major changes in the other cost factors.

It was felt that the results as well as the approach used to derive them, were reasonably sound. We recommend this approach for other areas where similar coastal resources management problems occur. How this approach can be used to train future resource managers will be discussed in Part IV of the series.

Acknowledgments

Thanks are due Hj. Abdul Halidi bin Mohd. Salleh, Selvanathan Subramaniam and (the late) Tatang Sujastani for helpful inputs and suggestions during the course of development of B:RUN.

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* ICLARM Contribution No. 1415.

D. Pauly, F.C. Gayanilo, Jr. and G. Silvestre *are from the International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati City, Philippines.*