A Technical Framework for a Sound Deployment of Passive Mariculture Devices in Shallow Waters:

Analysis, Simulation, and Prediction of Impacts of Fish Pens and Cages in Malalag Bay, Davao del Sur

A Comprehensive Report

by

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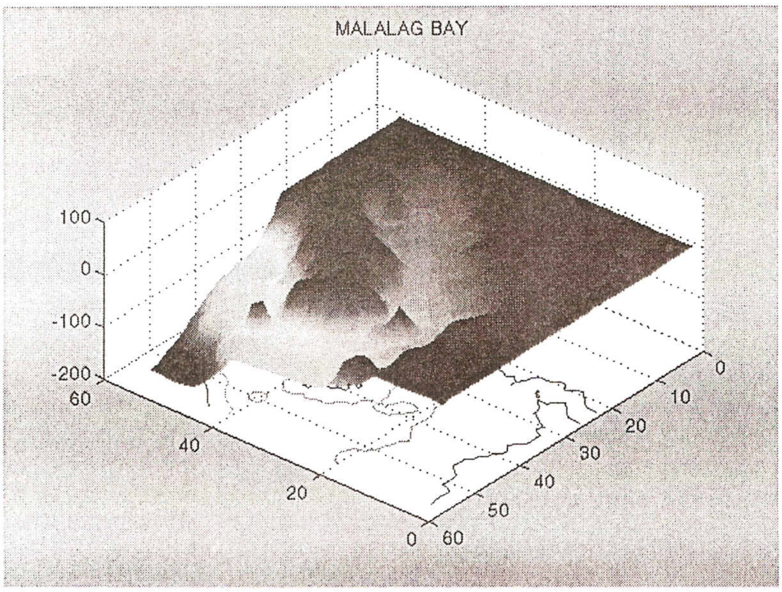

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1. INTRODUCTION

Environmental protection is one contribution of the Coastal Resource Management Project (CRMP) to sustainable use of marine resources in Philippine municipal waters. In this regard, the project carries out its so-called alternative enterprise development activites with appropriate constraints on the "carrying" capacity (CC, from hereon) of the environment. One of these activities is the promotion of well-regulated mariculture in CRMP learning areas, such as sea farming, ranching, and the grow-out of animals in pens and cages.

Malalag Bay, Davao del Sur is one learning area. It is situated inside Davao Gulf, which faces Celebes Sea south of the Philippine archipelago (Figure 1). Defined arbitrarily by longitudes 125°22' 35" - 125°27'10" E and latitudes 06°34'25" - 06°39'05" N, the bay encloses roughly 20.5 km^2 of water, an areal estimate that is delimited at the entrance to the bay. Five Davao del Sur municipalities (Padada, Hagonoy, Sulop, Malalag, and Sta. Maria) and ten coastal barangays surround the area along some 19.6 km of coastline, characterized predominantly by secondary patches of mangrove, seagrass, algal beds, and coral reefs (Garcia 1988). A map produced by a Local Government Unit (LGU) shows some information on the coastal habitats (Figure 2, Maceda 1998, personal communication).

Malalag Bay has become an area of concern because of the unregulated use of its waters. For instance, floating devices supporting the intensive culture of milk fish have congested the bay. Consequently, because it is hypothesized that the CC of the the bay has been surpassed to a point of destruction, CRMP is interested in assessing the impacts of the existing mariculture and pollutants, hoping that the assessment will help technicians, LGU's, and coastal resource managers plan for sustainable culture as well as prevention of damage to fragile communities the likes of mangroves, seagrasses, and coral reefs.

This study responds to the urgent and practical need of CRMP to determine specifically the CC of Malalag Bay relative to the density of fish pens and cages or, equivalently, the intensity of mariculture. A data-based methodology is developed to provide the sound technical basis for equitable and environment-friendly deployment of these devices. In particular, limited field measurements are fed to a computer model to produce a guideline for pen and cage deployment. A simple computer software is developed for this purpose. The software is applicable to shallow-water environment and thus envisioned as a solution package- as portable tool for generating advice on the crowding problem of passive mariculture devices in similar areas of the archipelago.

In line with its objectives, this study comes up with two main products: 1) an analysis of and recommendations on the existing water quality condition of the study area, and 2) a simple computer software for CRM practioners, for computing the suitability of a mariculture area. These deliverables are obtained within reasonable methodological bounds and availability of simple on-site measurements.

This report is a detailed account of the study that is complemented by a recipe of procedures to ensure the replication of the methodology by succeeding researchers. Section 2 discusses the materials and methods employed in the field, data processing, modeling, and packaging of the derived technology. The results are analyzed in Section 3, which discusses the field observations, derivation of useful culture indices, and the crucial role of water dynamics. Section 4 is the recipe of condensed layman's procedures, which outlines also the computational basis of Pens & Cages, the software developed in this study. Section 5 summarizes the limitations as well as the problems encountered by the study. Sections 6 and 7 present, respectively, the conclusions and recommendations. Other materials relevant to the study are lumped in the appendices: Appendix 1 is a non-technical Executive Report, Appendix 2 introduces the Dynamic Data-based Interaction (DDI) approach to management, Appendix 3 is an abridged manual of the software (plus 1-3.5" HD installation diskette), and Appendix 4 contains the raw database of this study in 1-3.5" HD diskette.

2. METHODOLOGY

This study sought for low-level technology suited for technicians. Consequently, field and laboratory methods utilized portable, unsophisticated instruments and protocols. Data were processed using simple procedures. Modeling was made transparent, its technical discussion kept to a minimum, and the model operationalized through an easy-to-use software.

2.1. Field Work

Determining the condition of a mariculture environment may require the joint analysis of field observations and model simulation output. The main objective of the field component was to provide the physico-chemical baseline for the environmental modeling. Another purpose was to derive from experience a pragmatic sampling protocol for CRMP. Relative to these objectives, the field work was largely a success.

Plans, equipment, and protocols were readied two weeks prior to the field sampling on 25-28 May 1998, which was participated in by nearly a dozen CRMP interns, LGU personnel, and a supervising researcher from the University of the Philippines in the Visayas (UPV), Miagao, Iloilo. The ideal sampling plan proved to be prohibitively expensive and time-consuming; thus, only 21 of the original 25 stations were occupied. However, these stations maintained a density of about 1 station/km^2 and were so chosen to represent three important zones- the fish pen and cage installations, fish sanctuary, and Balasinon River. Respectively, these typified sites with and without culture, and the main freshwater tributary (Figure 3). Timing of sampling minimized aliasing of the tides, which were suspected as the dominant forcing in the study area. Consequently, temporal coverage was pegged to three tidal phases: rising tide (RT), slack tide (ST), and falling tide (FT) (Figure 4). At times, during the sampling, the order of occupying stations was reversed to optimize the number of measurements (Figure 5).

The weather remained fair during sampling. The winds were light to moderate, and there was no precipitation. The waves were relatively small and favorable for travel within the bay area. Notably, the main freshwater tributaries were basically inactive. The overall condition reflected the on-going El Niño, which was blamed for the prolonged dry weather in this part of the globe. The absence of freshwater inputs was significant in terms of simplifying the analyses of the field observations. (See also Section 5 on the limitations.)

Only surface measurements of the following variables were obtained, on-board one pump boat, and directly with portable instruments and simple procedures (Table 1).

Table 1. Surface observations at 21 stations in Malalag Bay on 25-28 May 1998.

VARIABLE	METHOD
current speed (meters per second, m/s)	simple drift method (e.g. Baleña 1993)
current direction (degrees, °)	compass and boat orientation (e.g.Baleña 1993)
wind force (meters, m)	used height of wave as tentative measure of force
wind direction (degrees, °)	compass and wind sock
water depth (meters, m)	calibrated (m) sounding lines
dissolved oxygen (milligrams per liter, mg/l)	oxygen meter, YSI Model 57, Yellow Springs, Ohio
temperature (degrees Celsius, °C)	bucket thermometer
salinity (parts per thousand, ppt)	refractometer
transparency (meters, m)	Secchi disc
water color/substrate	visual

Optional sub-surface observations of temperature (occasionally of salinity) at five stations lining the axis of the bay (2, 4, 6,13, 18) were obtained, but only to verify depth variability and degree of mixing of the water column. A homogenous column was an esssential assumption of the modeling in Section 2.3.

Settling particulates and productivity were measured at the abovementioned representative zones (Figure 3). The particulates were collected by milk can sediment traps (diameter of 12.8 cm), which were either tethered or anchored somewhere between 4-16 m below the surface at an average exposure time of 63.22. On one hand, productivity was measured via dissolved oxygen (DO), through pairs of light and dark bottle setups. Each dark bottle was meant to completely block surrounding light, thereby precluding photosynthesis in it. Respiration of trapped organisms (plankton) was assumed equivalent for both light and dark bottles (an assumption that tends to be less tenable when the period of exposure is increased). Bottle pairs were set up for an averaged period of 5.88 h. Both settleables and productivity set ups and retrievals were timed favorably with the sampling of other variables.

2.2. Laboratory Processing

It was expected that some field samples could not be processed fully on the field. (However, it is emphasized that their subsequent pre-processing was ensured.) Indeed, due to limited time and logistics in the field, some samples had to be brought home to base, the Ocean-Weather Laboratory station (OWL at UPV), for the examination of turbidity, pH, dissolved, suspended and settleable solids (Table 2). The number and volume of these samples, and the manner they were collected were noted.

Table 2. Observations processed at the base station.

VARIABLE	METHOD
turbidity (Nephelometric Turbidity Unit, NTU)	turbidimeter, HACH Model 2100A, Loveland, CO
pH	pH meter, Corning Model 220, England
dissolved solids (milligrams per liter, mg/l)	DS/pH meter, Model DPH4, Myron L Co., Carlsbad, CA
suspended solids (milligrams per liter, mg/l)	filtering , oven-drying, and weighing of residue
settleable solids (milligrams per square meter hour, mg/m^2hr)	sediment traps

Turbidity samples, in 25-ml bottles, were measured repeatedly (3x) using a calibrated turbidimeter. The same samples were used to obtain the amount of dissolved solids (DS) and then pH, from averaging of at least three trials. In the case of the limited range of the DS meter (20 ppt, fresh to brackish waters), a remedial procedure was implemented. Samples of 4 ml were each diluted by 10 ml of distilled water (DW) in order to reduce solids content (14 ml was the capacity of the meter). Subsequently, the DS of DW (DS_w) was calibrated giving an averaged constant of 0.62 ppt, and the sample DS (DS_s) calculated as:

$DS_s = 3.5DS_m - 2.5DS_w$, where, DS_m is the DS content of the mixture. [1]

Larger samples of 350 ml were required for the determination of suspended solids (SUSPS), and the subsequent processing was rather tedious. Each sample was filtered on the field. Afterwards, the filter paper was folded over the filtrate, wrapped in aluminum foil, and transported in a labelled plastic bag. Before the amount of solids could be measured, each sample (now filter paper and residue) had to be dried in an oven for 1 h at a temperature of 100°C. Finally, the amount of SUSPS was determined by weighing. The dry weight of the residue (minus weight of filter paper) was expressed in mg/l given the 350 ml of water filtered.

Upon retrieval, settleables in sediment traps (SETTS) were filtered out and analyzed following the above procedure for SUSPS. The rate at which the solids settled out of the water was expressed in mg/m^2h.

Productivity was approximated using on-site DO at the time of set-up (DO_i) and those of the paired light and dark bottles upon retrieval (DO_l and DO_d), using the following relations:

Gross 1° Productivity (GPP, in mg/lh) = (DO_l - DO_d) / (incubation time, h), [2.1]
Net 1° Productivity (NPP, in mg/lh) = (DO_l - DO_i) / (incubation time, h), and [2.2]
Community Respiration (CR, in mg/lh) = (DO_i - DO_d) / (incubation time, h). [2.3]

To compare with other findings on local conditions (e.g. Castillo and Cuevas 1996), it was found convenient to express the above units into mgC/m^3d using these handy conversions:
(Note that the symbol for oxygen has been omitted for convenience.)

$GPP(mgC/m^3d)$ = 312.5 GPP(mg/lh) [3.1]
$NPP(mgC/m^3d)$ = 312.5 NPP(mg/lh) [3.2]
$CR(mgC/m^3d)$ = 375.0 C(mg/lh) [3.3]

However, the present study placed emphasis only on NPP to describe production.

Another DO derivative, the so-called 5-day biological oxygen demand (BOD_5), was calculated. Ideally, this parameter is determined at controlled temperature of 20°C, but this constraint was ignored for practical reasons. Assuming that the sample volume is the same diluted mixture referred to by Hammer (1977), the following were formulated to estimate BOD_5:

BOD_t (mg/l) = DO_i-DO_d(t), to obtain BOD using any incubation time t, [4.1]
BOD_u (mg/l) = $BOD_t \cdot (1\text{-}10^{-kt})^{-1}$, to obtain ultimate BOD, t in days, and [4.2]
BOD_5 (mg/l) = $BOD_u \cdot (1\text{-}10^{-5k}) \sim 0.3161\ BOD_u$, to obtain the standard BOD. [4.3]

Values of k for domestic wastewater varies in the literature from 0.1 to 0.23 and were found by this study to be too drastic. Instead, a more appropriate constant was calculated using an accepted generalization that 68% of the ultimate (carbonaceous) BOD is exerted in 5 days (cf. Hammer 1977, p.81). Using the last expression, the value k=log(.68)/(-5) ~0.033 (in units of $[T^{-1}]$) was obtained.

The entirety of field notes and observations were transcribed to a prescribed sheet for coding into the computer. (Some observations turned out to be largely optional for the purpose of this study. See Section 4.3.1.) A simple database routine was built to facilitate sorting because computerized sorting allowed, at the same time, the convenient decimation of observations according to tidal phase (recall Section 2.1). Subsequently, the observations were examined visually and analyzed statistically to isolate gross errors and reveal the significant variations. (For reference, an estimation of errors associated with local oceanographic observations had been done by Baleña [1995]). Actually, there are available spreadsheet softwares and sharewares to do all these tasks. The only requirement is for them to be able to save data columns in ASCII format, should one decide to use the P&C software developed in this study (Section 4.3.2 and Appendix 3).

2.3. Modeling

Modeling approaches to aquaculture vary widely and can be conceivably vague or complex (cf. Cuenco 1989). Discussion of this subject is avoided. Instead, a pragmatic approach is introduced. Its broader framework called Dynamic Data-based Interaction (DDI) is outlined in Appendix 2.

Modeling in this study provided the conceptual framework for building the software for fish gear deployment based on limited field data. Specifically, the work focused on computing CC or suitability of the water environment for mariculture. This was realized by comparing field and simulation results against DENR water quality standards. The simulation emphasized circulation as the primum mobile of water property redistribution or dispersion.

The outcome model was but a set of computerized routines. It may be thought of simply as a numerical computer program, or software, for automating the tasks of data formatting, computation, simulation, and collation. The user will find it convenient that these tasks do run in a single batch job, pre-supposing only that the observations are coded in their required formats.

The computerized steps may be outlined at this juncture. (The details are reserved for Sections 4.1-4.4 and and Appendix 3.) First, processed observations are read in by the computer. Second, these observations are interpolated uniformly in a grid. Intermediate routines compute for the respective components of the vector variables like the current, interpolate between RT and FT phases of the tide, and calculate BOD and NPP from oxygen measurements. Third, advective-dispersive simulation is performed to determine the dispersive ability of the current field. This stage offers the flexibility to modify sources of dispersants (or stocking density) as initial condition of the simulation. Finally, information are collated to produce a set of indices describing jointly the suitability of the environment.

Preliminary theoretical work commenced weeks before the field work. Initially, a barotrophic transport model (Flenniken and Chu 1989) was utilized to simulate circulation in the bay. Partial runs were made to evaluate the model. However, there was inadequate opportunity to make long and stable runs mainly because of power interruptions. Consequently, proper set up of boundary conditions was not achieved. Finally, with consultation from CRMP, modeling was revised for the better strategy of utilizing in situ current observations. This entailed the building of new routines, but which altogether required much less time to run and evaluate. The idea of exploiting on-site observations as model input is akin to the advantageous technique of data assimilation (Miller 1990). Indeed, the assimilation of the observed current field was found in this study to have eliminated excessive computations and guesswork in simulating the processes of advection and dispersion. In general, assimilation does not make a model purely prognostic nor predictive; instead, a model is made a compromise between computationally-involved predictive and non-evolving diagnostic models, incorporating advantageous properties from both, such as simulation capability and data-truthing, respectively.

Finally, mentioning the major assumption of the model is in order: The model works well for homogenous shallow water environments. Hence, considerable mixing of the water column is assumed usually as caused, for instance, by tidal or wind agitation. It is known in oceanography that the wind contribution alone may extend to depths of 150-200 m. In comparison, maximum depths in the bay were found to be in the vicinity of only 50-60 m. There are ample proofs in the following section of the considerable water mixing in Malalag Bay.

2.4. Technology Packaging

Consistent with the study objectives, the present methodology was packaged in such a way that CRM technicians could redo the present research effectively, with additional guidance from the lessons learned from the study. Cluttering of the procedures with optional comments and theory was reduced, producing the condensed recipe of Section 4. The software developed in this study was designed specifically to support this recipe by performing the tedious, technical processing and computations (see Appendix 3).

3. RESULTS AND DISCUSSIONS

This section discusses at length the outcome of the field data, and proceeds to derive empirical CC indices (serve as indicators of the mariculture activities) from knowledge of feeds and stocking density. Regarding the water dynamics, crucial distinctions are elucidated between the concepts of flushing, residence time, and dispersion. Overall, the findings reveal a degraded water quality condition of Malalag Bay.

3.1. Field Data Analyses

Meaningful interpretations may proceed from coherent plots of the variables with tidal phase. Beginning with the geophysical aspect, the following discussions focus on the condition of the bay as suggested collectively by the observations. Reference must be made also to Figure 3, Section 2.1, on the delineated environmental regimes of the bay.

3.1.1. Bathymetry

Bathymetry (BATHY) of the bay was digitized and then displayed using Surfer (@Golden Software Inc. 1990). The multi-dimensional rendetion is depicted in Figure 6. The study domain may be seen as a small indentation of the western coast of Davao Gulf (recall Figure 1, Section 1). Generally, the bay is shallow (values mostly ≤ O[10 m]), but its depth increases gradually norhtward, plunging eastward to the relatively deep basin of the gulf. Gridded depths ranges from 0 m (land) to 183.4 m, with an overall mean of 26.51 ± 37.34 m. A mound formed by corals (Bolton or Piape Reef, also seen in Figure 1) is situated near the entrance of the bay, posing as obstruction to water transport. Apparently, Malalag Bay resembles closely the configuration of a semi-enclosed estuary.

Coarsely sampled depths bear similarity with those interpolated from NAMRIA Chart No. 4656, revised 23 y earlier in 1975 (Figure 6, top figures). It is tempting to discuss also the differences, but a pointwise comparison of sampled and chart values could not be trusted.

3.1.2. Culture Gears

The precise locations of fish culture devices and sanctuary (zoned in Figure 3) is shown in Figure 7. A portable Global Positioning System (GPS) was used to determine the individual coordinates to within a maximum error of about 100 m. Some 21 pens, 732 cages, 13 corrals, and a sanctuary are plotted in their approximated sizes and distribution. A cage or pen has a mean area of 3.5 x 10 m^2 and depth of 3.5 m. Their combined effective area is small (26,355 m^2 or about .03 km^2), but their configuration, with unit spacing of about 300 m and inter-operator separation of about 60 m, occupies about 1.5 km^2 or a sizeable 7.3% of the bay area. The sanctuary has a variable reported area from about 1.4 km^2 to 1.7 km^2. If accumulated, the total culture and sanctuary footprint is roughly 3 km^2, representing 15% of the bay area, or nearly 30% of areas shallower than 5 m (which is 53.6% of the bay area). Evidently, human intervention of Malalag Bay ecosystem appears sizeable.

3.1.3. Currents

Currents (CUR) during the sampling period were relatively slow, hardly exceeding 0.25 m/s. The mean speed was about 0.19 ± 0.04 m/s with mean direction of 194.6 ± 107.3° (southwest). The sequence of plots in Figure 8 reveal the faint counterclockwise flows. During RT phase, water comes in the bay mainly in a soutwestward direction but, seemingly, hardly goes out of the bay, even during the FT phase. The superposed plot for all phases (CT) makes this feature and the circulation cells quite evident.

3.1.4. Winds

The wind was largely in consonance with the water flow (Figure 9). Its mean direction of about 98.6 ± 60.14° was almost westward. (Note: In constrast to current, in meteorology, direction is reckoned from where the wind comes from.) An indication of topographic steering in the inner portion of the bay, during the CT phase, suggests that the northern circulation of the bay, relatively, could be subject to more significant wind forcing.

Climatological data from PAGASA (Davao City) indicate a predominantly northerly winds (i.e. winds going south) during the month of May with a mean speed of about 2.5 m/s. The typical waveheight observed in the bay was in the vicinity of 0.23 m (±0.14 m), which translates also to a wind speed of roughly 3 m/s (extrapolated from Table 12.4, Pond and Pickard 1983). While the month of May is considered generally as a transition between the northeast and southwest monsoons, caution must be exercised in interpreting these results because a big El Niño event has disturbed the climate beginning sometime in 1997 (see also Section 5). El Niño is a climate anomaly that disturbs both ocean and atmosphere circulation patterns. A layman's account of the phenomenon is found in the Science and Technology Review section of Panay News (1997).

3.1.5. Dissolved Oxygen

An initial glance at the health of the bay can be gleaned from the DO plot in Figure 10. The observed range was from 6.0 to 7.7 mg/l, while the overall average was 7.2 ± 0.3 mg/l. Evidently, DO exceeded DENR's limit of 5 mg/l- in fact, for nearly all classes of coastal and marine waters (Classes

SA, SB, SC, and SD). Thus, Malalag Bay is revealed to have more surface oxygen than prescribed for its waters (cf. DENR-EMB 1990).

The relatively high surface concentration of oxygen in the bay is unlikely due only to atmospheric input because the saturation value of DO is only ~6.17 mg/l at the given observed conditions of T=30.51°, S=35 ppt, and atmospheric pressure (cf. Metcalf & Eddy 1991). Open water intrusion may also be ruled out because the mean oxygen content in the gulf region hardly exceeds 5 mg/l (Wyrtki 1961).

The DO distribution with tidal phase suggests a similar counterclockwise water movement observed previously.

3.1.6. Biological Oxygen Demand

Ironically, the oxygen available for animal growth could be restricted. Specifically, the BOD_5 of 15.60 mg/l, averaged from light-and-dark bottle sites (Figure 11 [top], also Figure 3, Section 2.1), exceeded even the maximum degradation requirement for Class SC waters of 10 mg/l. The computed value represented already about 31.6% of the ultimate BOD_5 of 49.34 mg/l. This means that the abundant oxygen in the bay was not really being made available for animal production.

The bay could have lots of unoxidized organic matter- a condition typical of polluted waters. These organic matter, which may take the form of proteins, carbohydrates, fats, oil, grease, urea, agricultural chemicals, etc., could be transported westward from the culture sites (generally also from land), causing the elevated BOD_5 at the western half of the bay as seen in Figure 11 (bottom, values extrapolated from station values of top Figure). The mode of transport is consonant only with the observed circulation (Section 3.1.3).

3.1.7. Productivity

Production was measured from the same sampling sites with BOD for gross primary production (GPP), net primary production (NPP), and community respiration or CR (see Figure 12). However, NPP was used conveniently as proxy of the bay's productivity. Interpolated plot for NPP, processed similarly as the BOD plot above, is shown in the figure.

GPP was relatively high (~22.00 mg/lh) north of the sanctuary and lowest (~0.03 mg/lh) at the site of the culture gears. CR varied from about 0.14 mg/lh near the sanctuary to 0.18 mg/lh at the culture site, suggesting the presence of more animal life there. Notably, NPP almost had an opposite distribution to that of CR, i.e. a maximum of about 6.56 mg/lh near the sanctuary and extremely low values of -18.50 mg/lh at the culture site. Thus, it is conceivable that the culture areas consume more of the bay's surface oxygen, a condition which makes them limiting for further growth. A westward spread of this unfavorable condition is apparent from the predominantly negative values (only a small area of positive productivity is seen near the sanctuary.)

3.1.8. Water Color

Additional support to the observed productivity distribution is provided by water color (Figure 13), which suggests also that the western sector of the bay, seen as more greenish, was relatively more productive. Remarkably, it is fortunate that, in this sector of the bay, the fish sanctuary had been located quite reasonably by the LGU (recall Figure 7).

3.1.9. Solids

Settleable, suspended and dissolved solids may comprised of sediments and waste of biochemical (aquaculture) origin: faecal and urinary products, micro-organisms, parasites, feral animals, chemicals and uneaten food (Beveridge 1996). All these hinder photosynthetic activities and the consequential generation of oxygen. Fortunately, for this study, the situation was simplified: Terrestial input of sediments may be assumed minimal because of the prevailing dry El Niño conditions (see also Section 5).

3.1.9.1. Suspended
Almost everywhere in the bay, SUSPS load was unusually high (Figure 14), attaining values comparable to that of a medium-strength untreated domestic wastewater (O[220 mg/l]). In particular, the mean SUSPS was 219.54 ± 96.51 mg/l, and values varied widely from 0.00 mg/l to 523.81 mg/l. This finding may have grave implications because it is likely for SUSPS to contain a large amount of organic matter which can cause the development of anaerobic conditions, or even sludge deposits. Precisely, in Figure 14 (bottom-left), the highest concentration of observed SUSPS is found in the culture area.

3.1.9.2. Dissolved
DS had a fairly uniform distribution, except for slightly elevated values near Balasinon River, which might actually be a major source of these solids (see especially FT phase, Figure 15). The mean DS was 41.9 ± 3.0 ppt, and values ranged from 37.1 ppt to 47.3 ppt. In comparison, untreated domestic wastewater of weak strength has a DS concentration in the order of 250 mg/l (Metcalf & Eddy, Inc. 1991) or only 0.24 ppt, when computed using a water density of 1025 kg/m^3. Hammer's (1977) ceiling for drinking water goes up to a concentration of 500 mg/l or about 0.49 ppt, while DENR's available limit for fresh waters is 1000 mg/l or about 0.98 ppt. Evidently, with the present situation, DS has exceeded this value by about 43 times- another solid evidence of an unhealthy water environment (Table 6).

Previous suspicion on the baywide mixing by the circulation is evidenced also by the relatively uniform distribution of DS.

3.1.9.3. Settleable
SETTS is a practical indicator of the intensity of mariculture activities. For this reason alone its lengthy discussion is warranted.

The bay had an appreciable amount of SETTS. Similarly with SUSPS above, Figure 16 shows clearly that more of the settleables fell from under the culture structures than areas removed from these structures, particularly, the fish sanctuary. Point SETTS samples from the cage area and river had similar means of 1640 ± 980 mg and 1970 ± 200 mg, respectively, suggesting that fish culture in the bay had caused considerable fallout, presumably due to wasted feeds, excretion, and possibly decaying matter. Considering the size of the sediment traps (128.68 cm^2) and the averaged exposure time of 63.22 h, these figures mean that, at the culture sites, every m^2 of the bottom was being showered by some 2000 mg of solids per hour. The next section shows that, already, this value exceeded environmental limits about 2-2.5 times.

On the other hand, the relatively lower value of 420 ± 160 mg at the sanctuary must be interpreted cautiously. Because water inside the bay appears to be well-mixed with time, the observed value may not characterize "pristine" water. In fact, mixing in the bay must involve considerable loads of materials because the value translates to a fallout rate of about 500 mg/m^{2}h, which is no longer too far from the computed limit of 800 mg/m^{2}h (Section 3.2). This finding suggests strongly that locating or relocation of sanctuaries must consider the water circulation because this is most influential in moving around pollutants. This suggestion is mentioned in the light of the recent indication that sanctuaries might be the only remaining frontier against rampant mismanagement, which has aggravated the rapid, continuing decline of fisheries (cf. Russ 1996).

The effective area of all pen and cage clusters is 26,355 m^2 (Section 3.1.2). If feeding by operators is uniform with time and amount, one may expect to collect an alarming 5.3 x 10^7 mg/h (53 kg/h) of settleable materials from under these clusters, say, during an intensive feeding season. Worse, the potential effect of the fallout may not be limited because the expanded areal configuration of pens and cages, including the interspaces, is about 50 times larger than the effective area of the devices themselves (Section 3.1.2)

3.1.10. Turbidity

The relatively high concentration of SUSPS in the culture area is corroborated by turbidity (TURB) observations (Figure 17). Notably, Malalag bay waters were found more turbid than the semi-enclosed, heavily-silted Batan-Banga Estuary in Aklan, where the predominant TURB was only in the neigborhood of 3-4 NTU (Baleña 1993).

TURB ranges from 2.4 NTU to 7.6 NTU with an overall mean of 4.9 $\pm$ 0.9 NTU. The range of values widened because of a local maxima at the bay's southeastern end (Figure 17, bottom-left). The already familiar mixing of solids in the bay, apparently in consonance with the observed currents, can be gleaned from the plots.

3.1.11. Transparency

Observations of transparency (TRANS) corroborated further the above findings on SETTS and TURB (Figure 18). In the mean, TRANS was in the vicinity of about 10.5 m. During RT phase of the tide, water clarity worsened to about 3 m at the western portion of the bay. This indicates that tidal mixing may be significant. While, during ST phase, clarity improved to about 12 m. The discrepancy of about 9 m suggests the strength of mixing, meaning that waters with depths $\leq$ 9 m could be stirred fully by the cyclic tide.

3.1.12. Salinity

Surface and sub-surface salinities (S) remained invariant at 35 ppt (within refractometer accuracy of $\pm$0.1 ppt) and are no longer plotted. Instead, it is useful to note that the discrepancy between S and DS can be used as a rough measure of many dissolved organic compounds (DOC). From the DS plots, we can infer a concentration of (42-35) ppt or 7 ppt as an average DOC loading in the bay (excludes nutrients and other pollutants). This is roughly only 2% of the mean DS but, certainly, cannot be ignored as insignificant relative to mean SUSPS of only about 0.22 ppt (~220 mg/l). In fact, the DOC estimate exceeds even the DS standard by about 7 times (Table 6).

The relatively uniform distributions of S, both horizontally and with depth indicate that, indeed, there is some homogeneity in the water column of Malalag Bay. It is worth mentioning also that the constant salinity of 35 ppt compares well with the historical mean maximum surface salinity of 34.7 ppt (Wyrtki 1961). The slight elevation could be associated with the El Niño.

3.1.13. Water Temperature

Water temperature (T) also remained almost invariant during the sampling with an overall mean of 30.3 $\pm$ 0.4 °C and a range of (31.5 - 29.7) °C or 1.8 °C. The means were almost identical during the RT phase (30.3 $\pm$ 0.5 °C) and FT phase (30.3 $\pm$ 0.4 °C), signifying a fairly uniform distribution. Further, a plot with depth clarifies that water mixing was not limited only to the surface. This is the final evidence that supports the sufficient degree of mixing of the water column in the bay (Figure 19).

Although it is uncertain whether the main cause of the temperature feature is the wind or the cyclical tide (or both), it is now justified to asssume that ample mixing of the bay waters occurs within about the sampling period of three to four days. This is a reasonable conjecture in view also of the fact that the mean thickness of the homogenous layer in the gulf region is known to be about 50 m (Wyrtki 1961), i.e. just about the maximum depths within the bay (Figure 6, bottom).

3.1.14. pH

There is an indication that pH, like DS, was associated with the Balasinon tributary and was distributed in consonance with the circulation (Figure 20). The overall mean of the pH observations was 7.4 $\pm$ 0.4, and the range was from 6.5 to 8.0, i.e. close to the limits found in Table 3.

3.1.15. Other Variables

Section 4.3.1. will show that, of the dozen variables measured in the bay, only pH, DO, T and S satified the standards. Because it appears that the general health status of the bay is unfavorable for mariculture, the suggestion is that these variables were not crucial in Malalag Bay mariculture. It will be nice to verify if this finding could be generalized for other mariculture areas. Moreover, there can be a host of interesting variables to study in any water environment and, obviously, the present list is limited- only for practical considerations. Indeed, for certain applications, one may find it beneficial to include in the analyses of Section 4.3.1 additional variables that have something to do, e.g. with toxic or heavymetals and coliforms. In the specific case of an aquaculture environment, nitrate, nitrite, ammonia, and alkalinity may be included. The only (practical) requirement imposed by the present methodology is the availability of low-cost simplified procedures. Other practical procedures for future consideration by this study are mentioned, for instance, in Hallegraeff et al. (1995).

3.2. Deriving Mariculture Indices

It is helpful to begin by relating the bottom fallout to the actual feeding rate at the surface, which is, in turn, related to stocking density. Information gathered from reluctant operators indicate that the feeding rate is six times per day at an average of 487000 mg/m^2. This translates to a feeding rate of about 123000 mg/m^2h, or 123 g/m^2h, which is numerically coincident with the average number of fingerlings stocked per m^2. Thus, a fingerling is showered practically by 1000 mg of feeds every hour. However, wastage is involved. Already, figures above (Section 3.1.9.3) suggest that some 1.6% of 123000 mg/m^2h, or 2000 mg/m^2 h, end up as fallout at an averaged trap depth of 11.7 m. It is conceivable also that some amount is lost to the water column.

Using the same values for the surface flux, fallout and trap depth, in the absence of ingestion by fishes, the water column must then concentrate some 10300 mg/m^3h (8.6 mg/lh) of feeds. This is a significant contribution to the observed SUSPS input of only 19300 mg/m^3h (16.1 mg/lh), computed from a change of 100 mg/l in half a semi-diurnal tidal cycle of 6.21 h. Since, DS was observed to be invariant throughout the observation period, the total input of solids to the water column (down to 11.7 m) due to combined SUSPS and DS may be retained at 19300 mg/m^3h, a hefty 53.4 % of which is due to feeds.

If desired, an exponential decay function may be invoked to compute for the extinction coefficient, c, defining the rate at which the amount of feeds given at the surface may decrease with depth:

$F(z) = F(z=0)\, e^{-cz}$, where F is the flux as a function of depth z. [5]

Using $F(z=11.7) = 2000$ mg/m^2h, $F(z=0) = 123000$ mg/m^2 h, the derived value of c is 0.35. This parameter is valuable for modeling feeds concentration anywhere in the water column given only the surface input (see also Sections 3.3.4 and 4.4.1). This assumption may work well in shallow waters of moderate currents and low vertical mixing, such that the settling period may be, at most, in the order of a few days (e.g. within one sampling period). Indeed, given a settling velocity of 0.00025 m/s (cf. Fritsch et al. 1989), to settle a particle to a given depth of, say, 60 m will take about 67 hours (see also Section 4.4.1).

The amount of feeds taken up by culture fishes as well as the uneaten food are relatively harder to ascertain. Piedad-Pascual's (1996) and Millamena's (1996) articles on feeds and feeding development serve as reminders of this tenuous problem. In the literature, feeding losses are placed on a wide range from 1% to 45%. Beveridge (1996) mentions the so-called food conversion ratio (FCR) of 1.3-1.6:1, which extends the upper range further from 30% to 60%. However, Beveridge (1996) mentions very valuable details pertaining to nitrogen (N), which are referenced in this study. Specifically, the uneaten part of N constitutes 20%; of the remaining 80% ingested food, 14.4% is converted to faeces, 42.16% to urine, and only 23.44% ends up as body weight. Thus, about the same amount of wasted nitrogen is converted to fish growth. Actually, the faeces and urine may combine with the uneaten food to regenerate in the water column some 80%N. At the same time with N, 60% phosporous (P) is regenerated also. The FCR of P is 1-2.5:1, suggesting losses from 0% (total ingestion) to 60%. A more concrete partitioning of elemental components was done by Costa-Pierce and Roem (1990) who found the C:N:P proportion in sedimenting materials as 1320:150:1 (and the relatively insignificant nutrient loss in feeds as1.54:1:0.) This CNP ratio is exploited also in the following discussions.

Adopting an averaged feed loss of 30% (confirmed by aquaculture experts), an input per m^2h of 123000 mg will result to a loss of 36900 mg which, assuming the above proportion, may be allocated to C:N:P as 33110:3760:20 mg. Equation 5 suggests that the 30% loss should occur at a depth of only 3.4 m, and the remaining 1.6%, at 11.7 m (caught by traps in this study). It is interesting that the earlier almost coincides with the typical depth of pens and cages (3.5m). We may coin this the feeds extinction depth (FED) since it implies the potential benefit of recycling feeds in these culture devices.

On the other hand, the total food ingestion per m^2h of 86100 mg (123000-36900) may be allocated similarly as 77260:8780:60 mg. Further, taking advantage of the above information for N, the amount available ultimately for fish growth may be estimated also for each C,N, and P components. Particularly, the 30% feed loss, the equivalent of N wastage per m^2h of 3760 mg, translates also to a fish biomass of 4410 mg. Hence, the corresponding values for C and P are 38720 mg and 30 mg, respectively. It is interesting to note that the total amount available for fish growth (43160 mg CNP) exceeds the wastage in feeding (36900 mg, above). Finally, to close the balance, the remainder of 42940 mg (123000-[43160+36900]), inferring from N data, should be mainly urine and faeces. A general summary of the feeding budget is schematized in Figure 21. Perhaps, most relevant to the farmer, is the derived relation for feeding, growth, excretion, and wastage of 123000:43160:42940:36900 or, simply, 3.33:1.17:1.16:1.00.

The preceding derivations did not account for the recycling of nutrients in the water column. This recycling is possible with the dissolution of elements coming from wastage and excretion. In the present case, the total of these sources per m^2h is 79840 mg which may, again, partition into 71640 mg C, 8140 mg N, 50 mg P. As mentioned previously, 80%N and 60%P of this will be recycled to the water column, which means 6510 mg N and 30 mg P. Remarkably, these are comparable to the respective values of N and P allocated for fish growth (above figure). This confirms the aforementioned significance of nutrient recycling or, equivalently, upwelling, in fish culture. Unfortunately, it is not quite straightforward to account further for the complex bio-chemical processes in the water column (cf. Beveridge 1996).

Finally, no matter how virtually small, the fallout flux of 2000 mg/m^2h (Sections 3.1.9.3 and 3.2) may serve as a crucial indicator of the mariculture intensity in the upper water columns by referring it to a limiting value. Exploiting the consensus on the accepted amount of feeds given to a stock, one is free to relate directly the fallout to the stocking density, which in the present case is 123 individuals per m^2. In fact, it remains only to estimate the limiting fallout in order to determine the "optimal" stocking density of the cultured fishes.

To illustrate, one may begin with the DENR limit for SUSP of 80-110 mg/lh (Table 3, Section 4.3.1). The ratio SUSPS/SETTS for Malalag Bay is about 100. Hence, the SETTS limit is roughly 800 mg/m^2h, which is far exceeded by the present fallout. (The lower limit was used in the calculations for a conservative estimate.) Therefore, based on this indication alone, Malalag Bay should decrease its mariculture activities by about 1.8 to 2.5 times. This may mean the equivalent decrease of the area, concentration of stocks, or number of pens and cages. (Compare also with update on Section 4.4.3.)

Indeed, the observed stocking density of 123 individuals per m^2 in Malalag Bay far exceeds the reported value for pen culture of 3 per m^2 (cf. Baliao 1984). Even traditional *lab-lab* enriched ponds maintains a stocking density of only 30-50 fries per m^2 (PCARRD 1983).

3.3. Water Dynamics

It is important to place the preceding analyses within the proper context of the dynamical character of the water environment. Hence, at this portion of the discussion, an index is necessary to describe the ability of the water body to disperse or flush out undesirable wastes or pollutants accumulating in the bay, especially those pertaining mariculture. For this purpose, a clear understanding of terminology is helpful.

3.3.1. Flushing

The usual concept of flushing as the "leaching out" or "dillution" of pollutant from a given water body can be misleading, first of all, because of its dependence on topography and the details of the circulation. Thus, for instance, in open waters (no enclosures), the concept is somewhat arbitrary, if not at all meaningless. Likewise, an observed circulation may not at all guarantee sufficient flushing of a "choked" configuration, e.g. that of Malalag Bay (Section 3.1.1). In both cases, it seems that one has to struggle with the fine details of a three-dimensional water circulation in order to track where pollutant particles come from and go- a laborious and more involved task that is not fitting to this study.

3.3.2. Tidal Flushing

For purposes of this discussion, flushing may be defined simply as the concentration of waste removed from the water body in one tidal cycle. Note that this definition may have nothing to do with the so-called residence time or the time a particle spends in that water body (below).

Using the concept of the tidal prism, one may compute from the range of the tides the difference betvveen the water volumes coming in and out of the bay. For instance, the tidal range for Malalag Bay may be taken as 1.9 m (Figure 4, bottom). The tidal prism is obtained by multiplying this with the area (Section 1), i.e. 20.5 km^2x 1.9 m or 3.90 x 10^7 m^3. This is the "active" volume of the bay. If one has the draining rate of this volume, then the time to flush out substances is determined. The entrance to the bay has a mean depth of 38.6 m and width of 3777 m, or an exit area of about 1.46 x 10^5 m^2. Thus, using a flushing speed of 0.15 m/s (from Figure 8), it would take roughly 30 min to drain a volume equal to the tidal prism. This is nice if only the pollutants are concentrated in the upper two meters and the circulation is a simple back and forth motion in the bay.

A more useful way to visualize flushing is to involve the pollutant concentration. The tidal prism is roughly 7.2% (1.9/26.3, tidal range by mean depth) of the volume of Malalag Bay, and that some 200 mg/l of supended materials is being introduced to the water column every tidal cycle (12.42 h). Assuming no further additions of SUSPS, the tidal prism of the bay will be capable potentially of flushing out all input solids in about 13.8 cycles (7.2 d, actually not so efficient flushing). As observed already, feeding in the bay is continuous; thus, excess feeds are bound to acccumulate in the bay. Of course, the calculation here is simple and does not take into account the distribution or redistribution of pollutants in the bay as determine by the actual time- and space-varying circulation.

3.3.3. Residence Time

It is worth recalling also a very familiar quantity. Formally defined in textbooks (e.g. Gross 1990) as the total amount of the substance (M) in the ocean divided by the rate of removal (or addition) of that substance (F), the so-called residence time (R) is used as the estimated time required to replace completely the amount of a substance in the ocean. This sounds like a relevant process, except that, again, one needs to define the boundaries of that "ocean" in order to utilize the concept.. After doing this, it is necessary to know M and further estimate F to compute for R. The procedure then is not as straightforward at it seems. Besides, R is so general a concept that it cannot refer to individual portions of a water body. For instance, the statement, "the residence time of substance X is 3 days" means only that all of X will be removed in three days. It does not distinguish whether X is found at the entrance or elsewhere in the water body.

3.3.4. Dispersion

But simply, one may gain further dynamical insight into the character of the flowfield by looking at the process of dispersion itself, which can be studied regardless of the bathymetry and topography of an area. Precisely, one can run a dispersal experiment to test the observed current field.

An operational definition could be useful. Let a current field have the flushing capability if it is able to disperse a given amount of wasted feeds (or any pollutantl, presumably 30% of input, within the known feeding interval of 4 h. Reckoned in terms of the local tide period (12.42 h, semi-diurnal), this is equivalent to dispersing 93% of the feed input per cycle. More precisely, because both horizontal and vertical dispersion are at work, a certain area may be characterized as well-flushed if, within the period required to settle a pollutant to the bottom (varies with coordinate), the horizontal circulation is able to move away from its source 93% of the original concentration in one tidal cycle. The process so described is so straightforward to simulate with the present numerical model (Sections 2.3 and 4.4.1). For the sake of completeness, in the presence of topographic enclosures, complete flushing must be subject to the additional constraint that the dispersed pollutants are removed by the tidal prism.

Moreover, a simple current profile, based on the 117th power law from boundary layer theory (Borthwick and Joynes 1989), may provide the variation of horizontal currents with depth. First, the average current components (U,V) may be computed from observed surface currents (u_O,vol as

$$U = u_0 7/8; \; V = v_0 7/8, \qquad [6]$$

which may be assumed to be situated at mid-depth. Then, given any bottom Zb, where the currents are assumed nil, the current at any depth z (u"v_z) may be calculated from a simple three-point Lagrance interpolation (e.g. Hornbeck 1975). The derived vertical current profile, together with the observed surface currents, simulate a crude yet useful three-dimensional current field of the study area. Additionally, one may incorporate in the simulation the settling (-vertical dispersion) of feeds beyond, say, the FED (3.4m), since dispersion occurs in three dimensions. For example, assuming a settling velocity of 0.00025 *m/s* (Fritsch et al. 1989), these solids will fall below the FED in about 3.8 h. Hence, potential feed pollutants would have just sank below the cages when the next feeding begins in 4 h- certainly, an undesirable situation.

It is informative to expand on the practical implications of the latter result. First, any intervening horizontal or upwelling circulation would help retain the use of feeds in the upper layers (conversely, pollute more these layers). Second, in view of flushing, to prevent the accumulation of settleables as substr'ate at 11.7m (trap depth), existing horizontal flows would have to clear them out within the associated settling period of 13.1 h. (Note that by then three more feedings would have taken place.) In Malalag Bay, the magnitude of current that would advect a particle from the bay's end straight to its mouth, given this time interval, is about 0.12 *m/s* (5550 *m/13.1* h), i.e. among the stronger observed currents. Another problem is that, particles, much like the current itself, cannot be expected to move in a direct route to the bay's mouth- not even during falling tides. Therefore, it is unlikely that, under the observed circumstances, flushing out of pollutants is guaranteed. Evidently, as argued repeatedly, flushing does depend on the actual variation of the current field. The means to circumvent these difficulties is found in Sections 3.2, 3.3.4 and 4.4.1, which show how simplistic ideas can be exploited in a numerical simulation.

4. RECIPE OF PROCEDURES

A simple-minded recipe of methods of observation and analysis, condensed from previous sections, is hereby outlined in sufficient detail to allow for future verification or application of the present technology. Notice that some details pertain to the requirements of the software that is built to support the recipe. There is an accompanying manual in Appendix 3 which explains the software installation and operation.

Very briefly, to obtain the suitability of an area for mariculture purposes, one has to make preparations, collect, process and input the data, and run a software.

4.1. Preparations

4.1.1. Bathymetry Setup

A map is needed all the time and is most crucial in the planning stage prior to sampling. For an area the size of Malalag Bay, NAMRIA's commercial bathymetric charts with scales from 1:20,000 to 1:25,000 are deemed satisfactory. Define the boundaries of the study area and grid it. The gridded map is the computational domain of the study area.

When defining boundaries, ensure that significant features of interest are included, and exclude as much land area possible in order to minimize the computational domain. Draw grid lines because these help locate features and charted depths. The maximum ground area considered by the software (below) is about 18.5 km x 18.5 km, corresponding to a mesh size of 120 x 120 cells, each cell with an area of 154.17 m x 154.17 m. In gridding, imagine superposing the mesh of 120 x 120 square cells over the map, while matching the correct ratio of map distance over ground distance. It is a simple matter to identify on the map the basic distance of 154.17 m and use this to draw faint grid lines on a photocopy of the map. As a quick guide to ground-map conversion, use 1° -111 km, 1'=1°/60-1.85 km, or 1"=1'/60-30.8 m. An optimal distance of 154.17 m is adopted as a compromise between resolution and computer memory. This distance may actually miss some fine transient (few days) features observed near the coast (cf. Francisco 1996).

4.1.2. Digitization

For computerization purposes, the depths printed in the map must be digitized. For example, the gridded map of Malalag Bay is shown in Figure 22. A grid point is an intersection of gridlines and corresponds to two coordinates, which define where it is horizontally and vertically- i.e. its location. It is most convenient to assign depth values to the grid points. However, printed depths in a chart may not coincide exactly with them. In this case, interpolate or find an estimate in between given values. As a first approximation, assign simply the depth value nearest to the grid point in question. This rough method allows a maximum placement error of -150 m, which is tolerable to the present methodology. This procedure is illustrated also in the above figure.

Bathymetry in NAMRIA charts is in fathoms and requires conversion to the standard SI unit of meter. The software does this conversion automatically. Alternately, there is a separate routine for this purpose that accompanies the software.

4.1.3. SamRling Plan

Planning is crucial to good sampling and should be made available way ahead of the actitivity. Matters to consider are the variables to measure, appropriate equipment, density of the stations, temporal sampling and duration, and number of people to do the job.

The number of variables should be just enough to describe water quality and flow conditions in the area. Section 4.3.1 lists a dozen such variables. Consequently, portable equipment must be used for rapid measurements and, when needed, any remaining processing must be unsophisticated. Most of the variables will have to be observed only at the surface. Sections 2.1 and 2.2 decribe the equipment and simplified procedures. Zone the study area according to observed dominant environmental regimes or features in the area, e.g. culture sites, sanctuaries, river mouths, seagrass community, etc., and design the number and distribution of sampling stations such that they represent adequately these regimes (at least three stations per regime). Zoning likewise reduces the number of prohibitively expensive measurements of variables like NPP, SETTS, and BOD (may have subsurface set ups also). Roughly, a sampling density 1 station per km^2 appears adequate relative to the present methodology. There are other factors for good sampling but, in the case of Malalag Bay, between about 20 to 40 stations, spaced no more than about 925 m apart appears reasonable. This recommendation arises from the limitation of one sampling boat. With ample resources, nine boats can improve sampling resolution down to about 100 m. The maximum separation of 925 m worked well in Malalag Bay, which may typify a semi-enclosed, well-mixed environment. As much as possible, for convenient referencing, make these stations coincide also with the grid points of the gridded map. Figure 3 plots both the zones and sampling stations. Sampling duration must cover three or more cycles of the local tide. This means a minimum of roughly 38 h if the tide is semi-diurnal (cycle of 12.42 h). Establish an early deployment and recovery of set ups for the abovementioned expensive variables, to save on subsequent processing time. For the other variables, secure at least three samples for each RT and FT phases of the tide. The sampling duration may be extended to meet this requirement. Finally, draw out a Gantt chart of activities and project resources as a function of time. The number of personnel, their duties, scheduling, and slack for emergencies may be determined. Provide everyone with prepared handouts and orient them on the coordination and documentation of activities. The number of personnel which proved adequate in the case of Malalag Bay was 12. See also Section 2.1.

The pragmatic methodology of Section 2.1 may be referenced to in implementating the field work. Additional reference to a standard text on water quality (e.g. APHNAWWAIWPCF 1985) is recommended.

4.2. Sampling

In situ observations are central to the analyses. Hence, collect and document them as faithfully as they are observed in the field. Errors may occur, but it is important that these are reported, too.

Except for NPP, SETTS,and BOD, variables need only to be observed at or near the water surface, although additional subsurface measurements may be done for some variables which require only portable equipment, e.g. T, S, and DO. There are simple tricks to further save time. Observe the waves and optimize sampling routes. Synchronize or reverse routes with the tides to fulfill coverage of the tide phases (recall Figure 5).

Ensuring an adequate temporal sampling, in conjunction with an optimal station configuration, is essential to producing good results. In addition, more rapid sampling will enhance accurate analyses. If no more than one boat is used, it is equally crucial to execute procedures rapidly to prevent timing inaccuracies and aliasing. Lastly, conditions on the field may change; hence, expect to make remedial modifications to your plan- at all times.

4.3. Processing and Coding

4.3.1. The Variables and Standards

The 12 variables, their standard limits, and nomenclature are shown in Table 3. (Future development of the software might consider additional standards like heavy metals, nitrate, nitrite, ammonia, and alkalinity.) Their detailed discussions were done in Sections 2.1 and 2.2. The procedures so discussed were straightforward, and it is important only to recall those precautions against commiting similar errors or difficulties. A color diagram in Appendix 1 (Figure A4) may help visualize the interrelationships among the variables. For the more enterprising researcher, a detailed explanation of the table follows.

Table 3. The necessary field observations. See also software manual in the appendix.

	VARS	DESCRIPTION	LIMITS
1	DO	dissolved oxygen at surface and in light-and-dark bottles , mrdl	~5.0
2	800	biological oxygen demand , derived from OO-i and 00-1 , mgll(5d)	7.0 -10.0
3	pH	measure of acidity,	6.0 - 8.5
4	5	salinity, ~oo	
5	T	water temperature, °C	≤ 5 3.0
6	TURB	lurbidity, NTU	1.2-3.5 (a)
7	5ETT5	settleable solids,mglm²h	5860 (b)
8	05	dissolved solids, ppt	50.9756 (c)
9	SUSPS	suspended solids, mf!.11	≤ 5 30.0; 80-110
10	NPP	net primary productivity; derived from 00-1 and OO-i, mf!.C1m.1d	828.3; -180.0-3369.7. (d)
11	CUR	water current speed, cmls	
12	CUR	direction, °	
		(a) open sea to silted estuary condition (Ba/efia 1993)	
		(b) inferred from ratio SUSPS!SETTSfor Ma/a/af!; Bay and SUSPS	
		(c) do not apply if backf2round is hiJ!her in concentration (new	
		(d) inferred from Ral7av Gulf (Castillo and Cuevas 1996>	

The environmental limits shown, mainly from DENR-EMB (1990), are those used commonly to describe the water quality of Class SB to SC coastal and marine waters, i.e. pertinent to commercial and sustenance fishing, wildlife sanctuary, mangroves and marshes, and recreational Class II waters. Only the following variables were found to have the suitable or derivable proscriptions: DO, BOD, pH, S, T, TURB, SETIS, OS, SUSPS,NPP, CUR (speed and direction). Note that their ordering and units are the same as in *tabvar.raw*, the input file of the software (Appendix 3). Some brief annotations are in order.

Aquaculturists may claim that bangus thrives best at salinities of 10-18 ppt. The lower limit is thus adopted for 5, while the upper limit allows for maximum values that may be found in coastal areas. The limits for T (28-31 °C) are, perhaps, representative of Philippine climatic conditions. The DENR proscription pertains more to the drastic changes introduced by industrial effluents generated, e.g. by industries, shipping, deployed power barges, coastal/harbor engineering, and quarrying. From any of these man-made perturbations, a general change in T of 3°C is considered disastrous. TURB is measured more accurately than TRANS. TURB limits are adopted from observations of a relatively stagnant estuary in Batan, Aklan (Balefia 1993). Only values away from heavy siltation and near the open sea are used. The DS maximum of 0.98 ppt (-1000 mg/l) is for Class A fresh waters. DENR limits SUSPSinput to within 30 mg/l. The lower limit of 80 mg/l is assumed as the sum of this value and that for Class A proscription for fresh waters. Similarly, the upper limit of 110 mg is derived from the lower limit. CUR has no available limit and is, certainly, difficult to assess because of its dynamic nature. However, CUR is the basis of simulation and thus the determinant of the distribution of other variables through its influence on dispersion.

Recall that, in general, measuring environmental variables is prohibitively expensive. The early trick done to save on resources was to identify only a small number of distinct but representative environmental regimes in the study area (Sections 2.1 and 4.1.3). For instance, in the case of Malalag Bay, only three such zones were required to represent the mariculture area, sanctuary (area free of culture) and tributary (freshwater inputs). It was only in these areas that the DO light-and-dark bottles and sediment traps were set up to obtain, respectively, the BOD and NPP, and SETTS. From these areas, measuremenst were decimated to other stations according to zone. SETTS proved to be the singlemost valuable source of information on waste generation due to fish culture. Calculation of its limit was based on the factor SUSPS/SETTS for Malalag Bay: The numerical value in the area of pens and cages was 186 (372000 mg/l/2000 mg/m^{2}h). Using the mean ratio and the lower limit of SUSPS of 80 mg/l, the SETIS standard was set more precisely at 860 mg/lh. NPP limits were derived from the work of Castillo and Cuevas (1996) on Ragay Gulf, one water body that was considered "clean" in spite of some anthropogenically-linked perturbations (Madamba et al. 1996). As indicated in Table 3, the range can be negative- presumably, when respiration exceeds production.

BATHY is no longer listed in the table but is given due attention because of navigational requirement. Navigable passages may be limited by a 5 m draught for fishing, recreational, and commercial vessels. Generally, water areas delimited by this depth must be reserved mainly for navigation. However, the actual amount of space devoted to passages may vary with locality. The tidal range, if it exceeds 5 m, must be used in lieu of the draught.

4.3.2. Coding

Finally, because a software awaits for inputs, code the12 observations in a prescribed format shown in Table 4. Multiple values coincident to a single station and phase may be averaged prior to running the software, or the software can do it automatically. Code also the digitized bathymetry as shown in Table 5. The plain DOS text editor is sufficient for all these coding tasks. Alternately, spreadheets like MSWorks or Excel may be used, but the coded files must be saved in plain ASCII/text format of readable characters.

4.4. Automated Computation of Suitability

Tables 4 and 5 mark the end of the hard work by the researcher. From hereon, the rest of the job will be done by the software. Refer to Appendix 3 for installation, test run, and formal application. For those interested in knowing what the software does, continue reading this section.

4.4.1. Computational Procedures

A series of computations are done automatically after the data coding. Two major programs were written for the task. Routines were programmed in Microsoft (R) FORTRAN version 5.10 (@Copyright 1952-1991 by Microsoft Corporation) and supported by graphical routines written in C + version

3.0 (@Copyright 1990, 1992 by Borland International, Inc.) The first program automates data processing and extract a set of suitability indices. A single batch job reads in the coded observations, computes for statistics, and interpolates values, when necessary. The second program does the simulation of DISP or, equivalently, the fate of feeds (or pollutants) in the water column. The simulation computes for dispersion given CUR and BATHY. DISP is the last of the computed suitability indices.

Interpolation of observations to the standard 120 x 120 mesh is done to facilitate computerization. An efficient objective method is used, which accounts for the scattered distribution of the observations (Balena 1992). Ancillary routines are incorporated to the computations to obtain BOD and NPP from DO measurements and process the vector variable CUR. Separate files are maintained for each variable per (RT or FT) phase of the tides.

It is worth mentioning that the present simulation technique has flexibility on input concentration of pollutants, which may incorporate user information on feed distributions/sources, wastage, and SETTS. The advection-dispersion algorithm developed presently was found simpler and more efficient than the one adopted by Borthwick and Joynes (1989) from the 4th order formulation of Crowley (1968). Moreover, new empirical values for the dispersion coefficients were found as kx~kl'~0.0102 m^2/s, matching conditions on the field. (In contrast, the lateral mixing coefficient by Borthwick and Joynes (1989) was nearly four times [i.e. accelerated] at 0.0376 m^2/s.)

Finally, the suitability indices derived from the procedures are combined and compared with a standard set of criteria shown in Table 6. Scoring is expressed in simple percentage. There are various fancy methods to summarize ratings, but the weights of variables were combined simply in a linear fashion to obtain the final rating for suitability of mariculture. SUITABILITY is designated as LOW (unsuitable) for values between 0-33%, MEDIUM (conditional suitability) for 34-67%, and HIGH for 68-100% (suitable).

Recall that, everywhere in this study, the word *suitability* is being used as an operational proxy of the CC of the water environment.. An alternate (and useful) rating indicating the amount that the CC is exceeded (E) may be obtained also as:

$$E = (S/100)^{-1}, \text{ where } E \neq 0. \quad [7]$$

A graphical program is available for displaying the detailed zoning of the study area according to suitability or E. The detailed numerical values may be saved from the outputs of the program. In sum, CC via suitability is derived conveniently from automated computations. However, as a strong word of caution, final evaluation and usage of this index as well as other outputs must involved human intelligent discretion.

A sample output.file of the computations is shown in Table 7. All output files may be plotted to display their individual contributions to the distribution of suitability. The computed suitability of Malalag Bay is shown in Figure 23. Its spatial average of about 40% translates to E-2.5, which coincides with the previously calculated projection from a fallout index (Sections 3.1.9.3 and 3.2).

The essential details to setup and run the software are documented in a short manual (Appendix 3). Interested users may actually redo all the calculations discussed in this section.

4.4.2. Pens & Cages- The Software

The operationalization of the simulation model (Section 2.3) is realized through this simple computational and visualization software (Appendix 3). Herein named as *Pens & Cages* (P&C), the software is a low-technology management tool for the deployment of fish pens and gears, and is designed mainly for the non-technical personnel..

Essentially, the software computes for environmental indices and compare them with DENR criteria. Two automated steps are involved: 1) the objective and systematic processing of limited field observations (static calculation), and 2) simulation of dispersion in an observed current field (dynamic calculation). The outcome is a set of scores describing the suitability (or non-suitability) of the environment for mariculture.

4.4.3. An Effect of Updated Observations

Consistent with the DDI tenet (Section 2.3 and Appendix 2), additional observations on the field will only improve certainty of the current results. Moreover, good results is the key to making good predictions which, in turn, should be the backbone of good environmental management. I cite in the following specific case how the result on suitability may be affected by updated observations from the field.

A year after the project sampling in May 1998, a re-count found a reduction in number of fishing structures by about a factor of 10 (Garcia 1999, personal communication). Expectedly, the direct effect should be a commensurate decrease of waste generation, which could be parameterized by the reduction of solids (Section 3.1.9). A recomputation reveals that this reduction increases suitability by about 12.2% (recall Sections 3.2 and 4.4.1). in reference to Figure 23 (Section 4.4.1), the suitability increase appears, on the average, to have insignificant effect on uplifting the condition of the bay (MEDiUM) although, in detail, the change does upgrade closer to HIGH suitability the condition of some portions of the bay.

The main non-trivial lesson learned from this case is that a positive response from operators on decreasing their number of gears will not result necessarily to an overwhelming (desired) positive response from the environment.. For one, a number of variables (other than solids) will have to be taken into account.. Another important reason is the unknown lag in the environment's response, which might be understood only if there were simultaneous updates also of other variables; in fact, in this regard, the preceding estimated increase of 12.2% is subject to uncertainties due to the use of past values in the re-computations. These new findings here suggest that the adoption of DDI in resource management necessarily means obtaining updates of all concerned variables as they may altogether be mutually time-dependent..

5. LIMITATIONS AND PROBLEMS ENCOUNTERED

Mentioning the major concerns of this study is in order.

1. The guiding philosophy of the methods rests on the DDI concept (Appendix 2), which means that additional samplings will only improve current results. Therefore, readers still must be cautioned that these results apply most appropriately to conditions prevailing during sampling, and that further observations are necessary if one desires to project the methodology. Recall that the study sampling was biased by an El Nino occurrence. This highlights the need to represent, e.g. the opposite condition (La Nina) as well as the seasons.

2. Determining suitability via a variety of parameters is subject to biases on the choice, number, and ranking of these parameters; the adopted linear assumption on their combination represents only an initial attempt to model what might actually be a complex, non-linear problem. When simplified procedures are finally found or developed, parameters like nitrate, nitrite, ammonia, and alkalinity may be included in the list of standards, as they might be beneficial to diagnose waters that support mainly aquaculture. In general, there should not be any constraint on inclusion of any other variables like toxidheavy metals and coliforms. Until accurately determined, the general uncertainty of aquaculture parameters are expected to influence the results.

3. Sources of pollutants were identified mainly with fishing gears, but it must be understood that point sources and the general terrestrial contribution had their net effect on the analyzed condition of the bay.

4. Special mention must be made of the potentially wide application of the methodology to the subject of general risk or quality assesment,which may not only be limited to the water environment..

5. Prediction is a very tricky business. Non-experts are not encouraged to make generalizations beyond those suggested by the results and ensuing analyses in this study.

6. Finally, ideas in this study are evolving and may not appeal to many scientists. However, it is felt that some systematic approach to managing the dynamic environment must be in place and, hopefully, should inspire especially those scientists handicapped by meager research resources. It is within this well-meaning spirit that the 001, as a tool, was conceived.

The actual problems encountered by the project were few, although serious enough to delay the schedule of activities. Field problems were related to the inavailability of measuring and processing equipment, difficulty of sampling deep areas, and the remoteness of the study area from the base of the project at UPV, Miagao. A research associate and graphics programmer did not perform as expected. Intermittent but frequent, unannounced power outages were fatal, causing erratic malfunctions to breakdowns of computer facilities and annoying delays.

6. CONCLUSIONS

This study achieved its main objectives using a methodology bounded by practical limitations.

First, a generous amount of analyses of the condition of Malalag Bay was produced from limited on-site observations, and the ensuing recommendations were founded solidly on these observations. Further, a layman-type recipe had been extracted from lengthy procedures to allow interested researchers to redo similar work.

The observations point to the fact that the bay is dynamically incapable of flushing wastes from on-going mariculture activities (and other unspecified sources). Circulation and mixing appear appreciable but, seemingly, their influence is confined by the configuration of the bay. Most water quality variables respond to this predicament accordingly. For instance, while the bay could have photosynthetic activities producing ample oxygen, many organisms (surface and subsurface) were respiring, too, consuming this oxygen. Or, simply that the bay could have lots of unoxidized organic matter. Indeed, suspended and settleable solids had been found considerable, as corroborated also by turbidity and transparency data, and there were indications that these were being dispersed mainly within the bay area only. Empirical derivations revealed further the proportions relating culture indices especially to the stocking density. A useful operational definition of "flushing" has been derived and worked out using unsophisticated formulations. Finally, a concrete measure of the bay's degradation was found to be about 2.5 times over the limit..

Second, Pens & Cages, a software utility, had been built to support the procedural recipe. The software computes for suitability (operational proxy of CC) based on limited field informations and the water quality standards. The detailed distributions of the variables were additional outputs. The software is easy to install, set up, and operate and should be simple enough for users with limited background on computerization. A test application of the software was successful: The computed suitability revealed that the whole bay was conditionally suitable for mariculture, in corroboration with the above estimated value on the degradation of the bay.

In short, the environmental condition of Malalag Bay had been quantified and could be interpreted in terms of equivalent proscriptions on feeding rate, culture area, or stocking density.

The following summarizes further the more significant findings or contributions of this study:

·establishment of pragmatic field and laboratory protocols
oformulation of equation for OS, from OSm and OSw
·derivation of BOOs and k=O.033, in units of [1"]
oMalalag Bay bathymetry is shallow and semi-enclosed, depths are within the SOm-homogenous layer

°the water flows in Malalag Bay hardly exceeds 0.25 mis, form irregular counterclockwise pattern, and conceivably driven also by northerly winds
°DO within DENR limits but NPP and BOD very low; possibly lots of consumers and/or unoxidized organic matter; productivity distribution corroborated by COLOR
°sUsPs load high, least contribution from sediments due to dry spell by El Nino; TURB like that of a heavily-silted estuary, corroborated also by TRANS
°DS within limits and invariant; salinity distribution uniform; DOC roughly 7 ppt and significant
°some 53.4% of total solids input to the water column (sUsPs and Ds) could be due to feeds
°sETIs excessive, like that of domestic wastewater; measured fallout from feeding (at 11.7m) is 1.6% of input but exceeds the limit about 2.5 times
°sETIs (fallout) and sUSPS are found as most helpful indicators of culture intensity or supportable fish stock
°formulation of exponential decay (with depth) equation with c = 0.35
°total culture area is 7.3% of bay, roughly 15% of areas shallower than 5 m
°sanctuary not "pristine"- within about 62%, near fallout limit
°bay's water column homogenous with respect to 5, T, its shallow depths, and other variables; baywide mixing possible in few (3-4) d
°coining of FED, feed extinction depth; FED coincides with the bottom of pens and cages; relevant to recycling
°recycled Nand P is the same order of magnitude as respective values for growth
°demonstration of implications of recycling within pen and cage devices
°derivation of the proportion for feeding, growth, excretion, and wastage of 3.33: 1.17: 1.16: 1.00
°operational definition of "flushing"; the bay is poorly-flushed; dynamics of circulation emphasized repeatedly
°Malalag Bay, based on the suitability index, was found conditionally suitable for mariculture; of the dozen variables, only pH, DO, T, and 5 satisfied DENR limits- this is interesting to verify, in other mariculture areas.
°the testing of the software was successful; the software is now useable for similar applications

7. RECOMMENDATIONS

An awareness campaign is advisable, precisely, to forewarn stakeholders that Malalag Bay is no longer "healthy" and thus needs to be regulated. It is recommended to ease down culture intensity by 2.5 times, meaning either the proportional reduction 1) in area of culture, 2) of stocking density, or 3) in feeds. The spatial details on this constraint are provided by the suitability distributions of the water quality variables, which may be used also to rezone human activities. Included in the proscriptions are the detailed considerations of areas shallower than 5 m, navigational lanes, tributary sites, potential sources of pollutants, and sanctuaries.

As a word of caution, the seemingly gentle approach (to stakeholders) of rezoning mariculture structures can be deceptive. First, it does not cater truly to any of the above options. Second, rezoning may, instead, encourage expansion of intensive culture activities from their present crowded sites. On the other hand, there are available suggestions. First, alternative or mixed culture is advantageous if some species (including plants) could survive on low feeds or feeds accumulating in the substrate. Second, a more attractive (dynamically) approach is to time intensive feeding during the southwest monsoon period (presumably the time for enhanced flushing), and then decrease gradually the feeding (or the culture) through the other season. As a guide, it takes about a week to clear out of the bay the excess feeds after every feeding. Additionally, a spatial consideration is the seasonal (dynamic) relocation of fish structures along the east (west) coastline of the bay during the southwest (northeast) monsoon to help confine feed accumulation in these structures. Eventually, through the years, this cycling, which exploits the monsoon seasons, might lead to a revived environment. . Note that this concrete dynamic suggestion to resource management complements if not reflects the sanctuary concept (Alcala and Russ 1990). Finally, finding an alternative site or means of livelihood is, of course, always an available option.

P&C software is being recommended for multi-application to mariculture areas. In the spirit of 001, the tool will only improve if validated by additional sets of observations representing different conditions in the field. An improved database may ensue from this mode of evaluation. In this regard, more field samplings are recommended for Malalag Bay.

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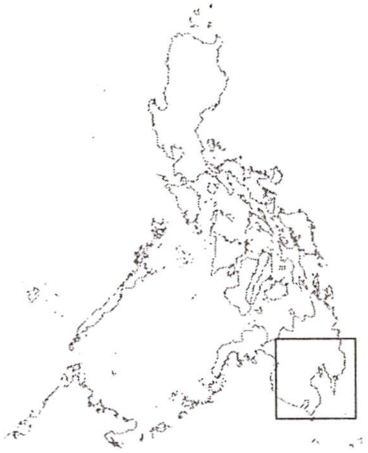
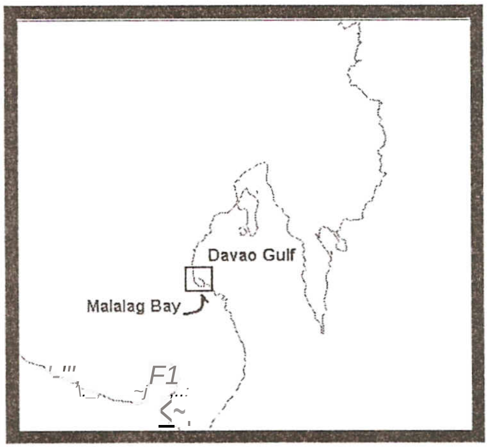
NOMENCLATURE

APHA	American Public Health Association
ASCII	American Standard Code for Information Interchange; "plain text," readable by all computers
AWWA	American Water Works Association
BATHY	bathymetry
BOD	biological oxygen demand
C	carbon; also Centigrade; also a programming language
CB	community-based
CC	carrying capacity
CD	compact disk, a computer storage medium
CNP	carbon, nitrogen,and phosporous
CR	community respiration
CRM	coastal resource management
CRMP	Coastal Resource Management Project
CT	combined tide
CUR	current (speed and direction)
C^{++}	a programming language advanced from C
d	day
DDI	dynamic data-based interaction; (a new term coined in this study)
DENR	Department of Environment and Natural Resources
DISP	dispersal or flushing ability
DO	dissolved oxygen
DO_i	DO initial; measured before setting up light-and-dark bottles
DO_l	DO taken from light bottle
DO_d	DO taken from dark bottle
DOC	dissolved organic compounds
DOS	disk operating system
DS	dissolved solids
DS_m	dissolved solids content of (sample+ OW) mixture
DS_s	dissolved solids content of sample
DS_w	dissolved solids content of OW
DW	distilled water
EM	environmental management
EMB	Environmental Management Bureau
F	rate of addition or removal of substance M (calculation of residence time)
FCR	food conversion ratio
FD	floppy disk
FED	feeds extinction depth; (a new term coined in this study)
FORTRAN	FORmula TRANslation, developed by J. Backus c. 1956
FSDP	Food Systems Development Project, a joint UPV-McGill University-Canada project
FT	falling tide
g	gram
GPP	gross primary production
GPS	global positioning system
h	hour
HD	hard disk; also High Density
IBM	International Business Machines Corporation
ICLARM	International Center for living Aquatic Resources Management
IDRC	International Development Research Center
l	liter
LGU	local government unit
IOCG	a user file containing his input of the locations of pens and cages or sources of feeds
m	meter
M	amount of substance in a water body (calculation of residence time)
MB	Malalag Bay, Davao del Sur; the study area; also megabytes (1 "million" bytes) - 2^{20} bytes
mg	milligrams
min	minute
ml	milliliter
mm	millimeter
MS	Microsoft Corporation
N	nitrogen
NAMRIA	National Mapping and Resource Information Authority

NPP	net primary production
NTU	nephelometric turbidity unit
O_2	ogygen
OWL	Ocean-Weather Laboratory
P	phosporous
PAGASA	Philippine Atmospheric, Geophysical and Astronomical SelVices Administration
P&C	Pens and Cages; the software developed in this study
PC	personal computer
PCARRD	Philippine Council for Agriculture and Resources Research and Development
ppt	parts per thousand
R	residence time
RAIN	rainfall
RT	rising tide
S	salinity
s	second
SEAFDEGAQD	Southeast Asian Fisheries Development Center/Aquaculture Department
SETIS	set1leable solids
SI	Systeme International d'Unites (International System of Units)
ST	slack tide
SUSPS	suspended solids
SVGA	SuperVGA
T	temperature; also denote the dimension of time as in rr']
TURB	turbidity
UPLB	University of the Philippines at Los Baiios
UPV	University of the Philippines in the Visayas
USAID	United States Agency for International Development
VGA	Video Graphics Array, a graphical display standard format
WIND	wind speed and direction
WPCF	Water Pollution Control Federation
y	year
YSI	Yellow Springs Instrument Co., Inc. (Yellow Springs, Ohio, U.S.A.)

ILLUSTRATIONS
Figures and Additional Tables





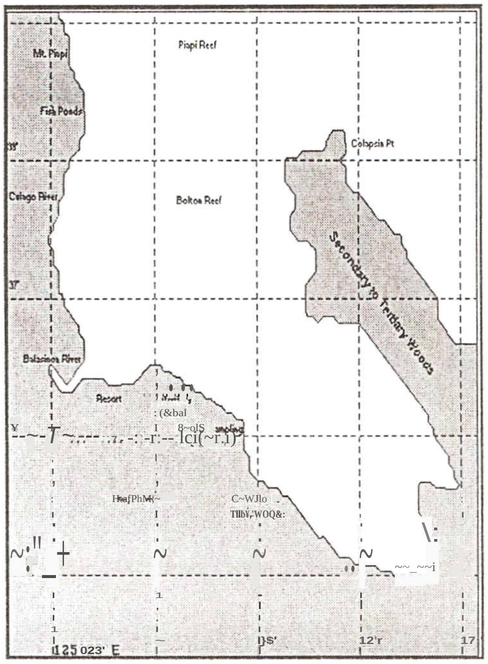


Figure 1, Malalag Bay, Davao del Sur.
The study area, as sourced from NAMRIA Chart NoA656, plus some updated features. Bolton (Piape) Reef forms a sub-surface mound that blocks the entrance to the bay, Boundaries: Longitudes125°22'35"-125°27"10" E and latitudes 06°34'25"-06°39'05" N, Water Area- 20.5 km^2, Coastline-19,6 km,

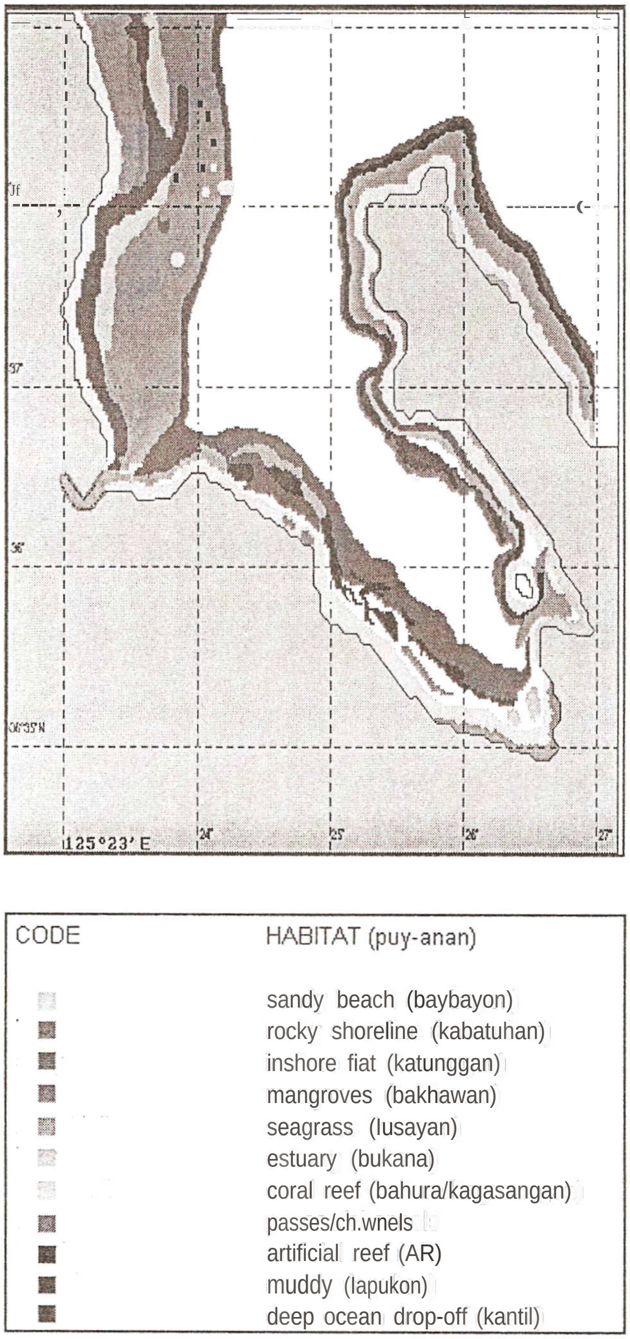


Figure 2. Coastal habitats.
Redrawn from a map compiled by an LGU. Local dialect is enclosed inparenthesis. Source: Maceda 1998 (personal communication).

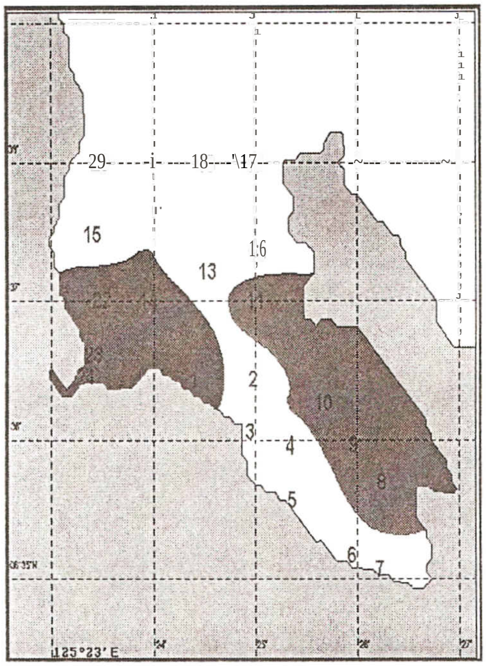


Figure 3. Characteristic Zones of the Bay.
Shown are the 21 sampling stations and the zones representing three different environmental regimes: mariculture zone (Stations 8-11), fresh water tributary zone (Stations 1, 14, 22-24), and "free" zone (Stations 2-7, 13, 15-18, 20). The latter includes the fish sanctuary in the vicinity of Stations 4-6 (Figure 7.)

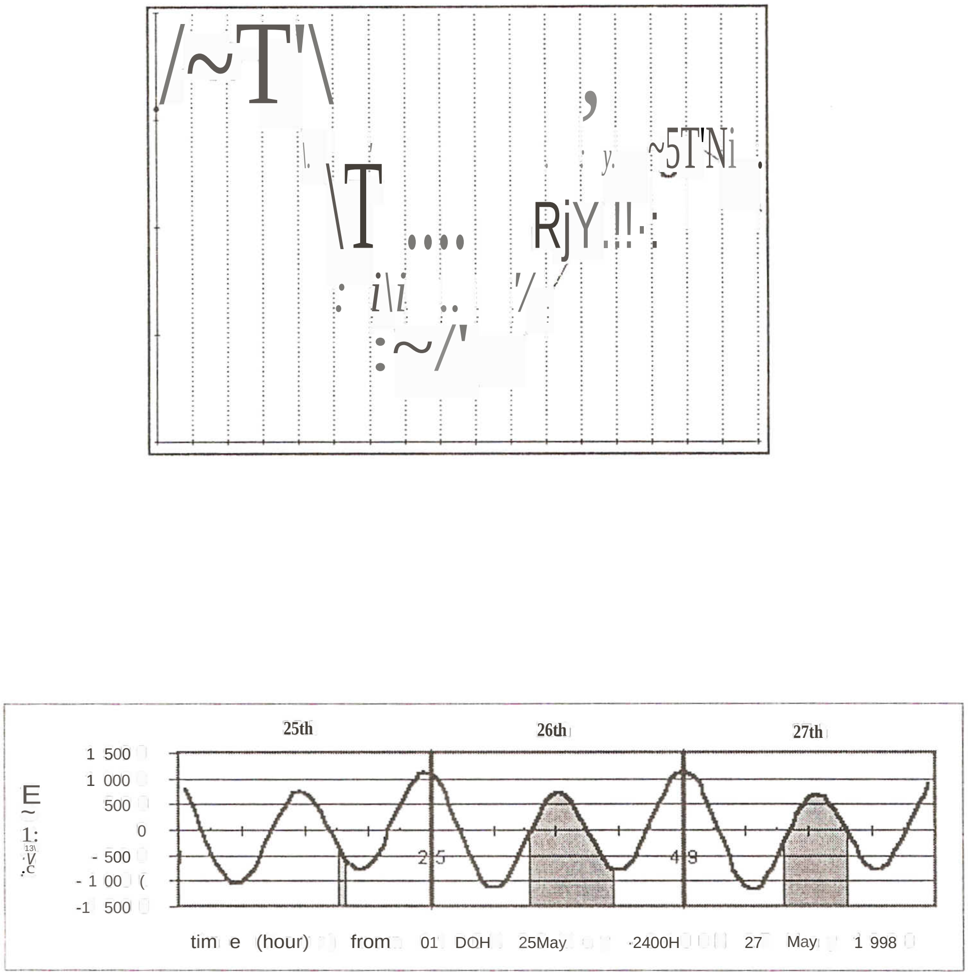


Figure 4. Phases of the Tide.
Nomenclature of phases: RT-rising tide, ST-slack tide, and FT-falling tide (top). It was important to sample the RT and FT phases. Shaded areas indicate the actual sampling hours in Malalag Bay (bottom). The tide in the bay is predominantly semi-diurnal. Tidal data may be obtained from NAMRIA's "Predicted Tide and Current Tables."

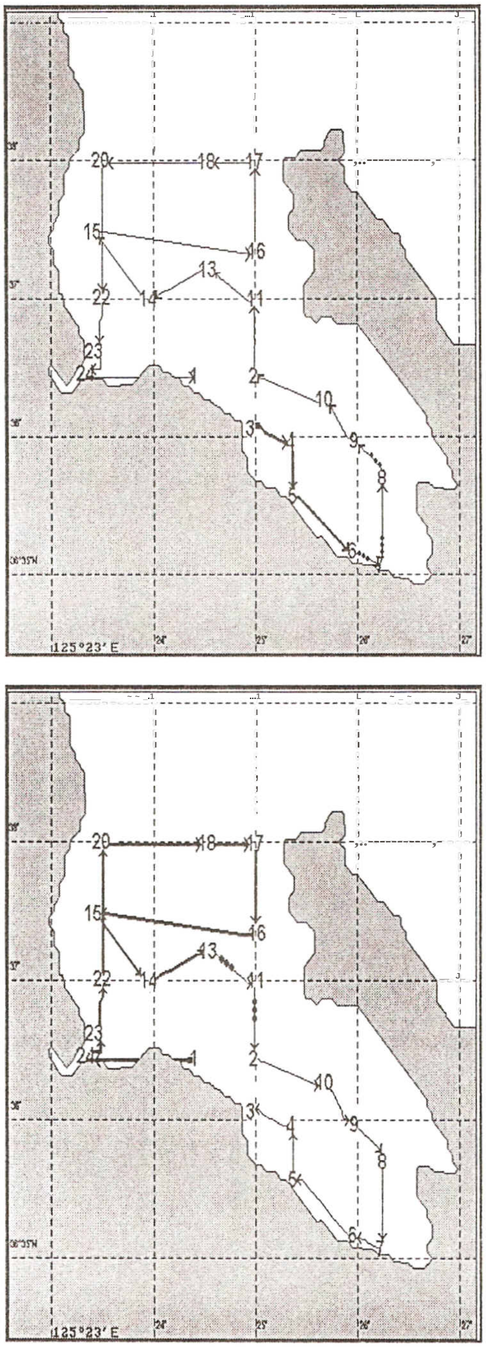


Figure 5. Sampling Routes.
Routes were optimized with respect to tidal phases, RT- bold, FT- thin, and ST- dots, Top: 26 May 1998, Bottom: 27 May 1998,

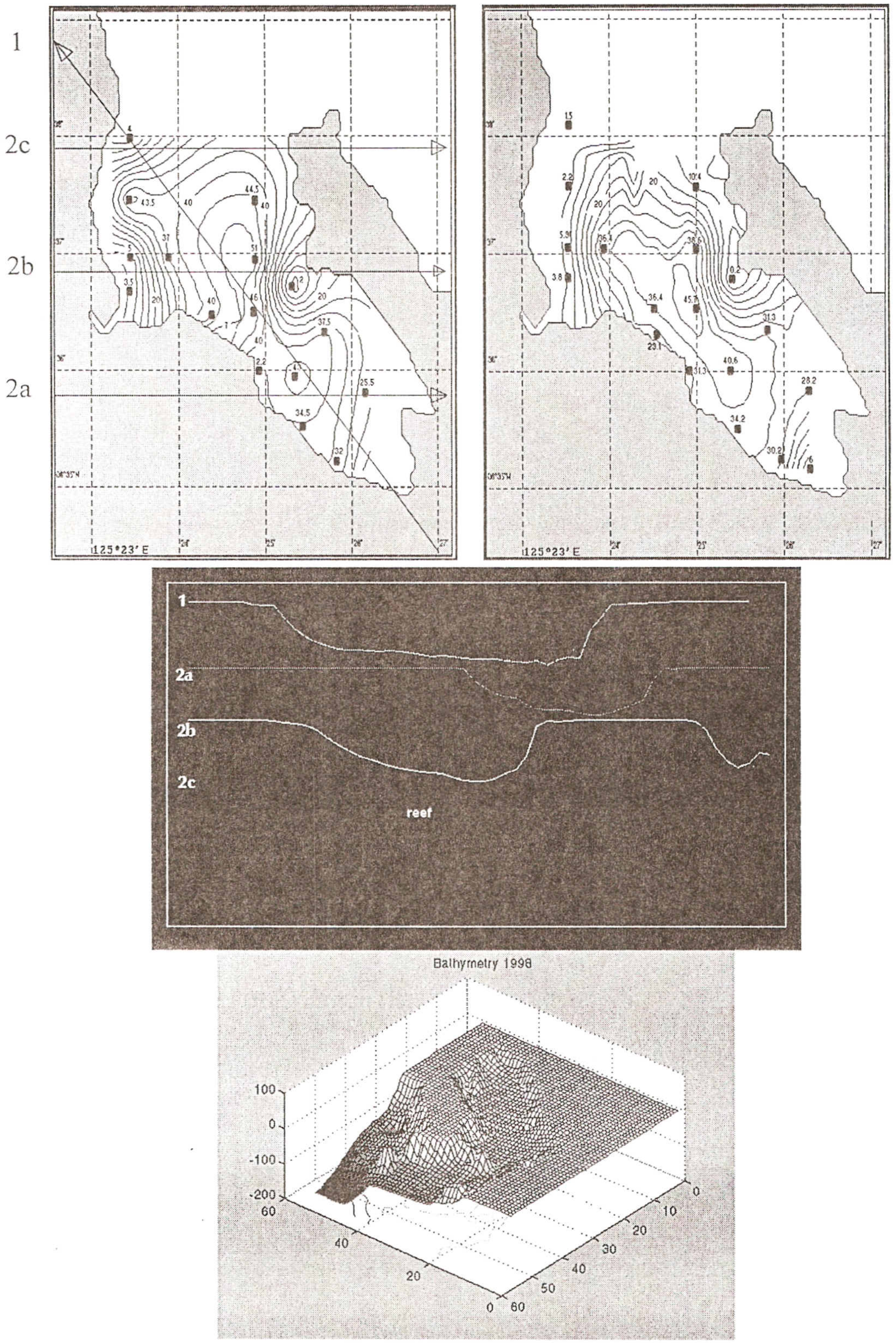


Figure 6. Bathymetry.
Digitized bathymetry of Malalag Bay. Top-left: From coarse sampling. Top-right: From corresponding interpolated values from chart. Middle: Depth profiles taken from marked sections of top-left figure. Bottom: 30 rendetion, viewed from the northwest at an elevation of 60°, data from **NAMRIA** Chart No. 4656 c. 1975; Bolton (Piape) Reef is seen at mid-entrance of the bay.

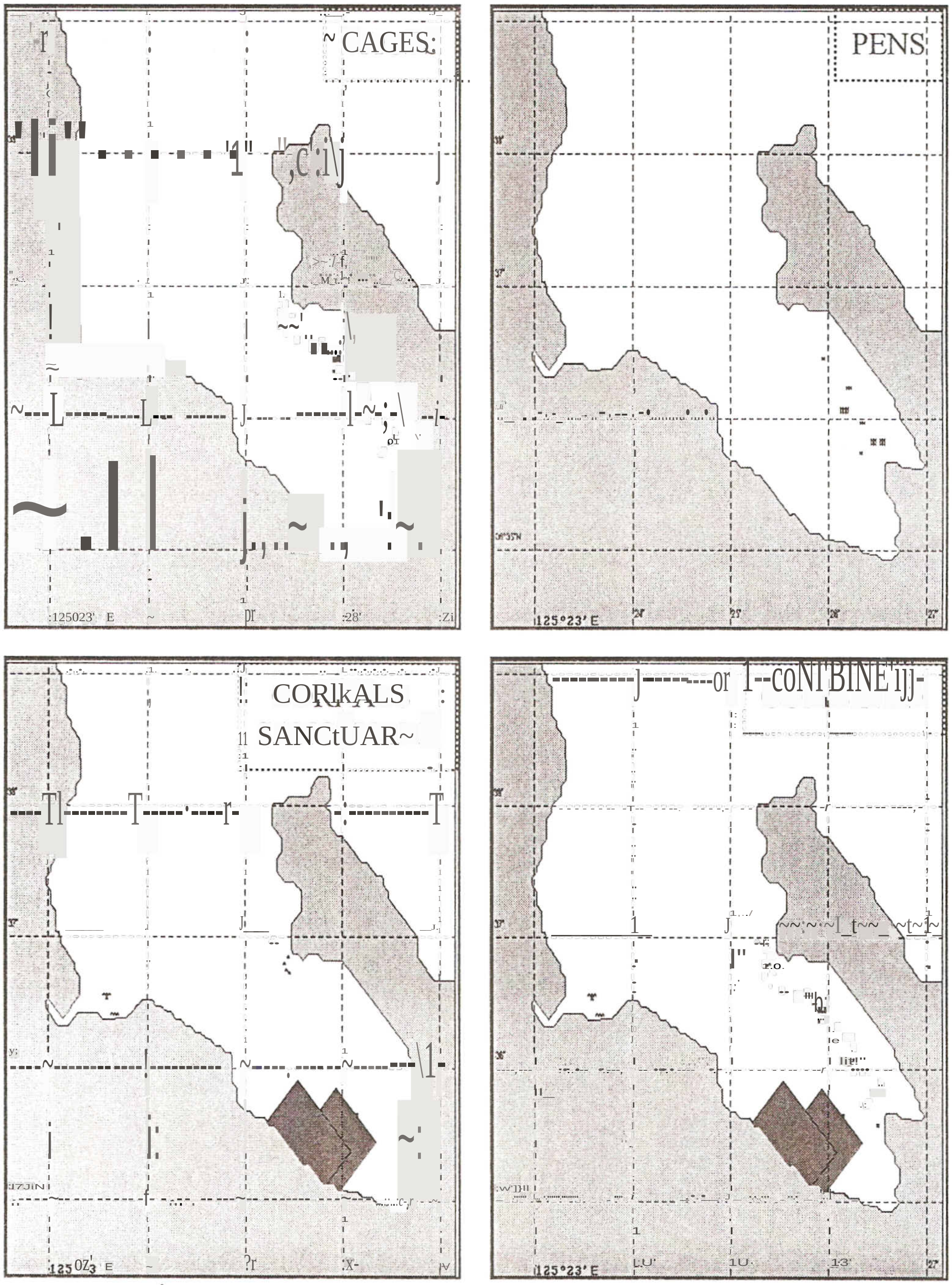


Figure 7. Fish Culture Gears and Sanctuary.
Clockwise from top-left: fish cages/clusters, fish pens/clusters, all structures combined, and fish corrals with the fish sanctuary (rectangular- based on municipal ordinance, Diel 1983; diamond- drawn from position of marking buoys). All structures were scaled approximately to their actual sizes and locations. Symbols used are H for pens, square for cages, and caret for corrals.

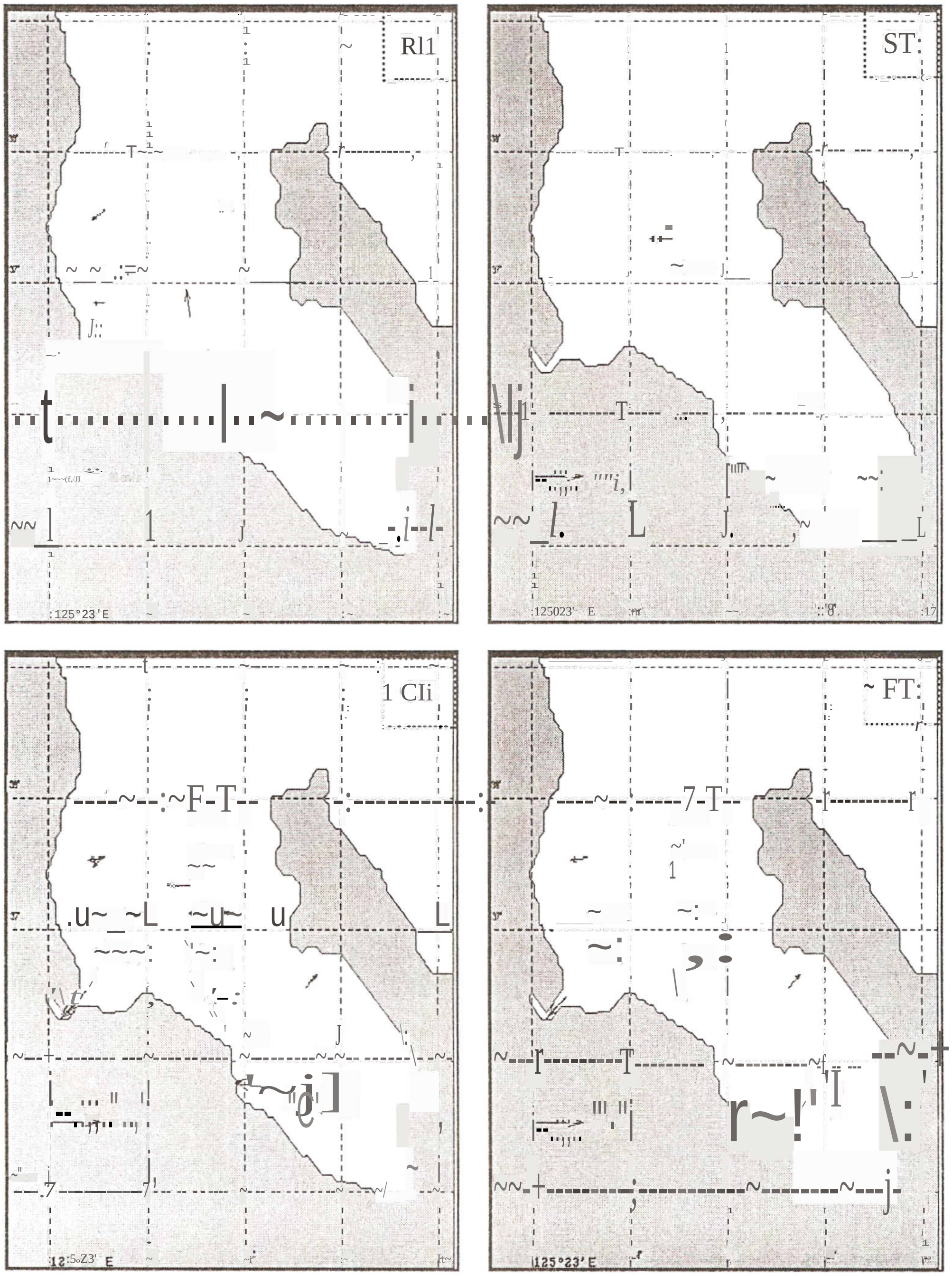


Figure 8. Currents *(m/s).*

Clockwise from top-left: during RT, ST, FT, and CT phases of the tide. For viewing convenience, the plotted scale is in cm/s.

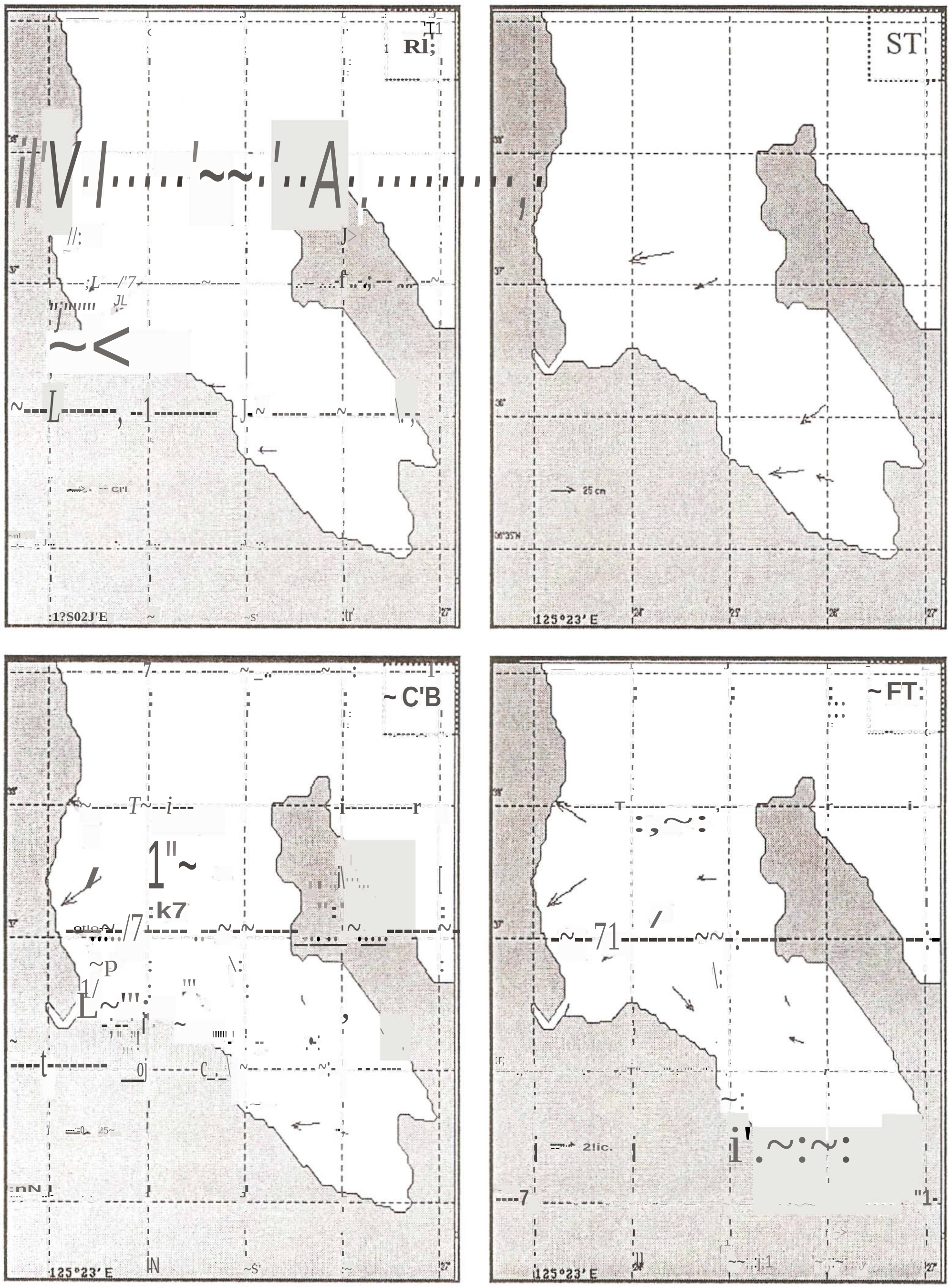


Figure 9_Wind (m).
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide. Wind force/magnitude is in terms of wave height (m), direction in degrees. For viewing convenience, the plotted scale is in em.

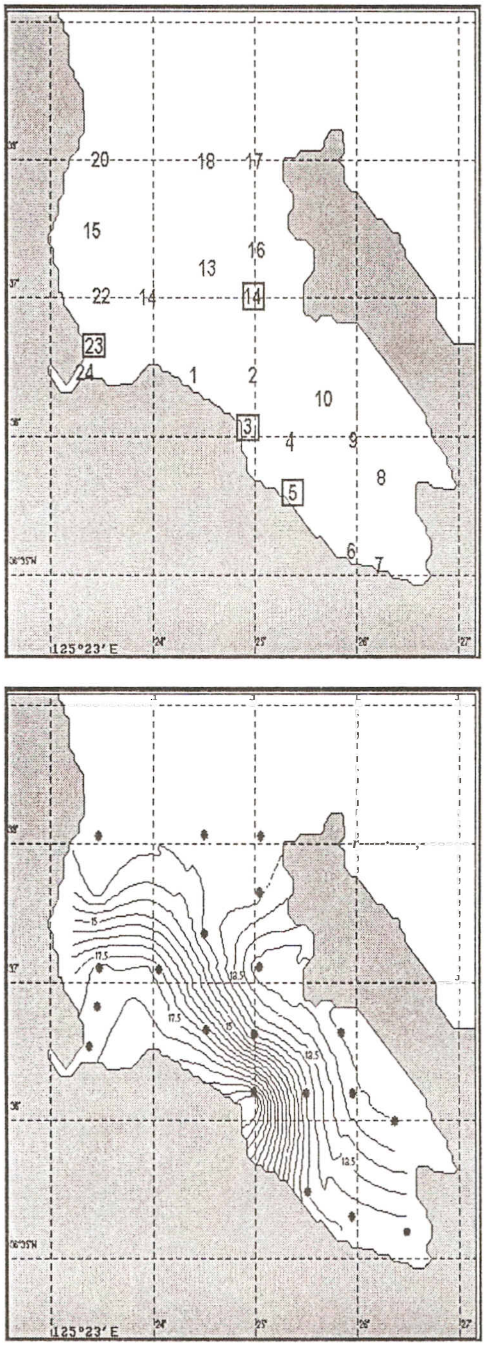


Figure 11. Biological Oxygen Demand (mgll).
Top: Sampling sites, also for productivity and settleable solids; Zones of Figure 3 are represented. Bottom: Extrapolated contour of BOD.

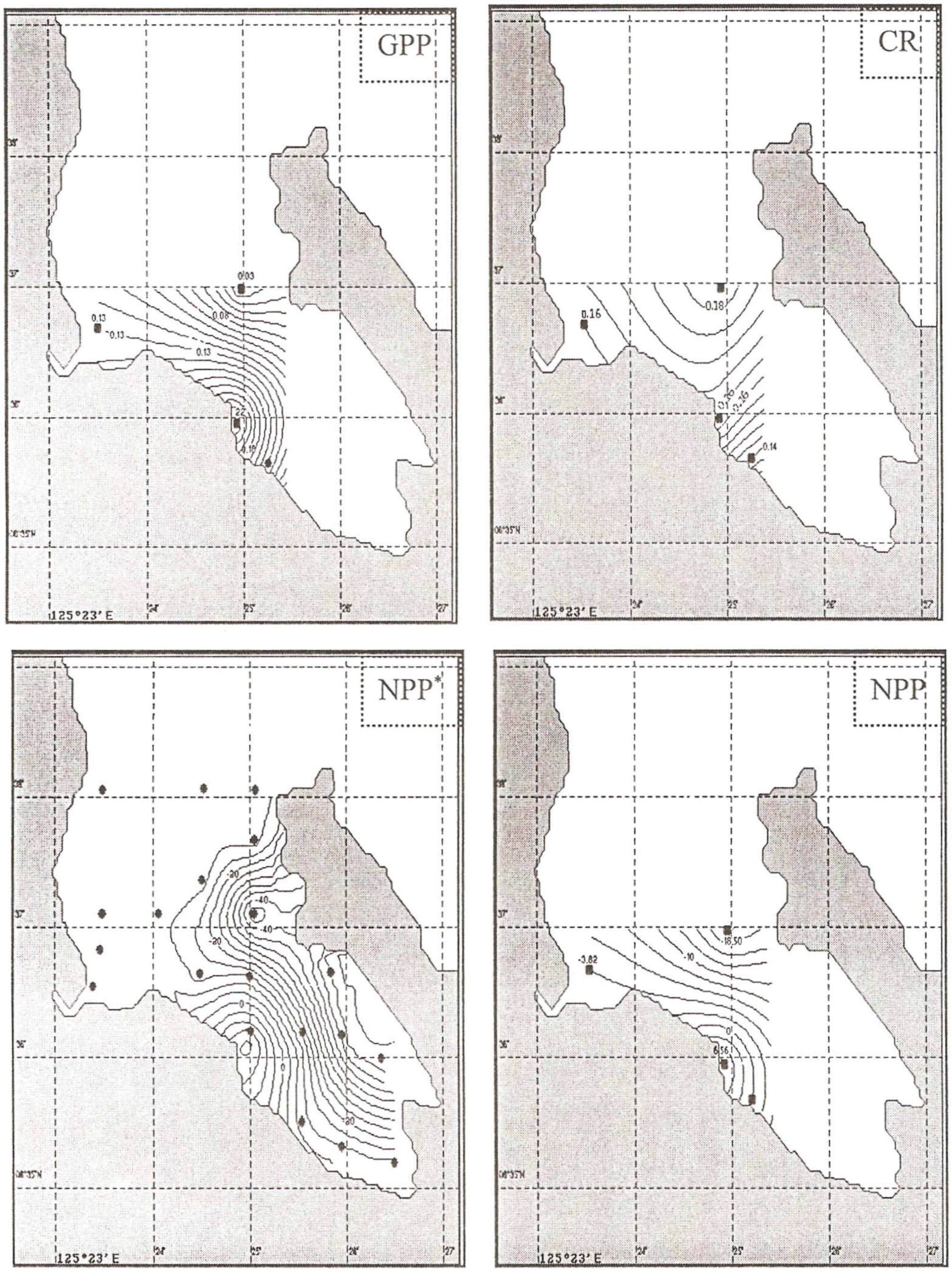


Figure 12. Productivity (mg/lh).
Clockwise from top-left: Gross 1° productivity, community respiration, net 1° productivity, and extrapolated net 1° productivity in units of mgC/m^3d. These variables were measured only at four locations, as in Figure 11. For the latter plot, the dots mark the original sampling stations. Values at these stations are extrapolations.

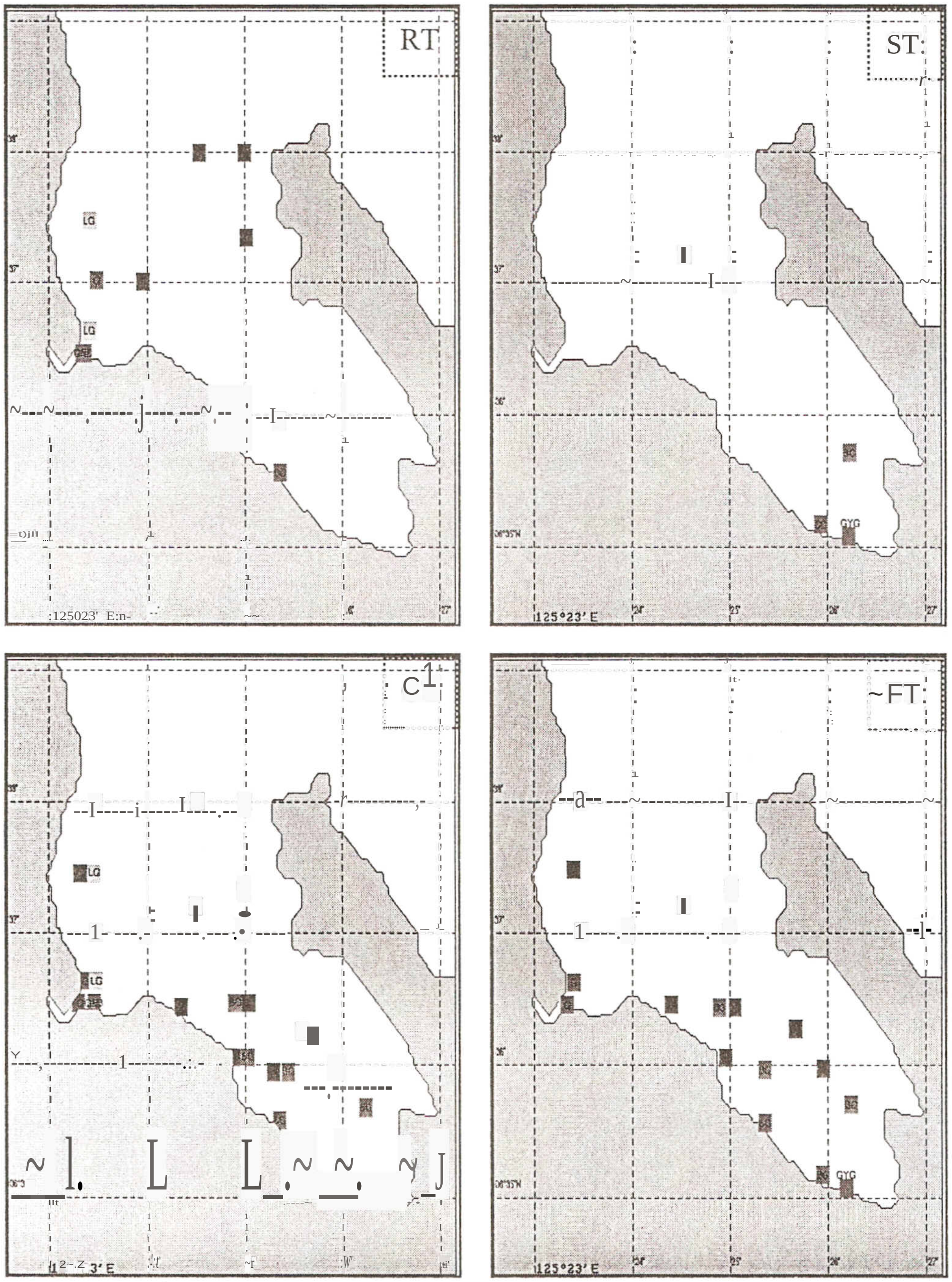


Figure 13. Color.
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide. Greenish portion of the bay is relatively more productive.

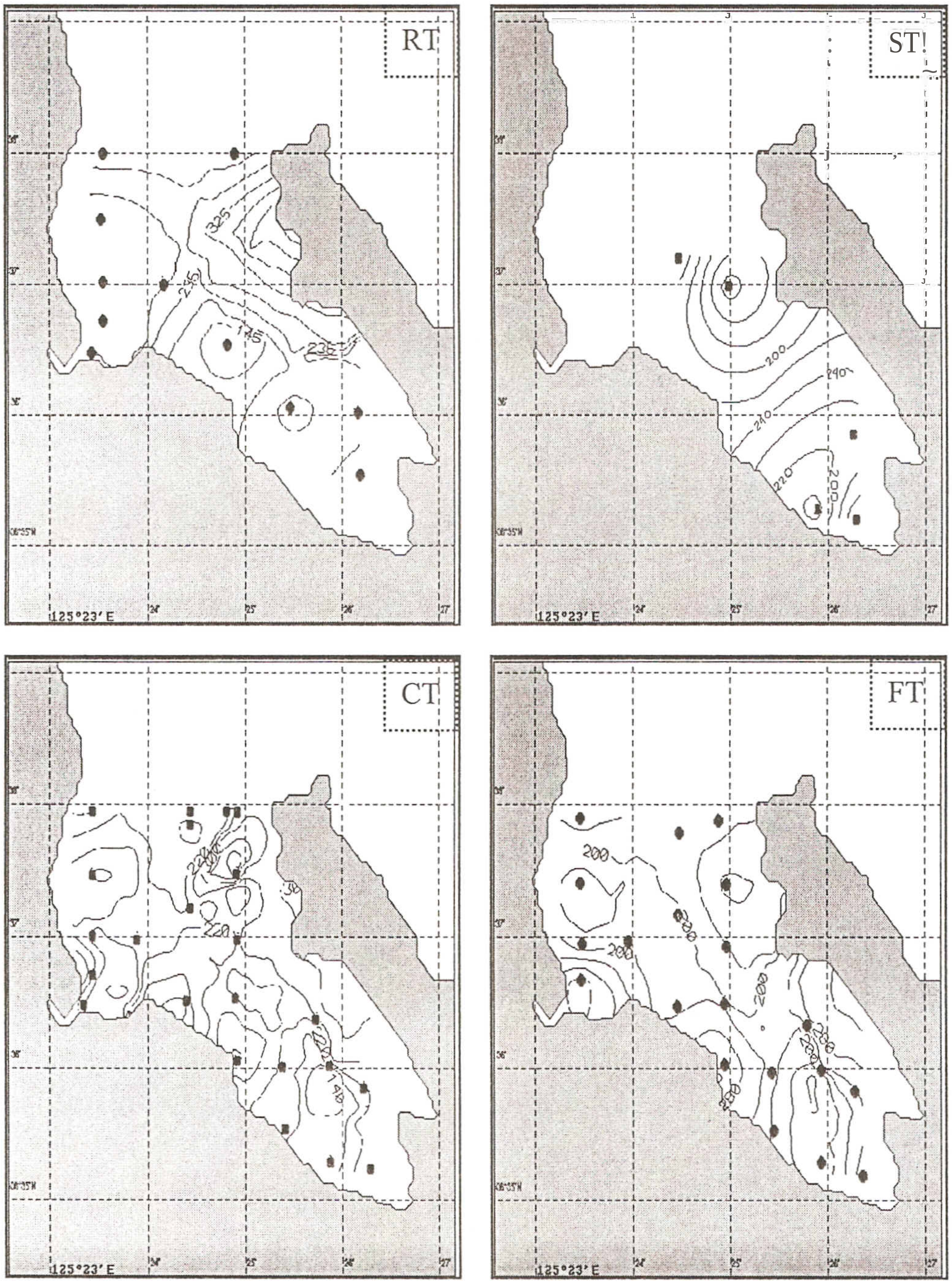


Figure 14. Suspended Solids (mgll).
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide.

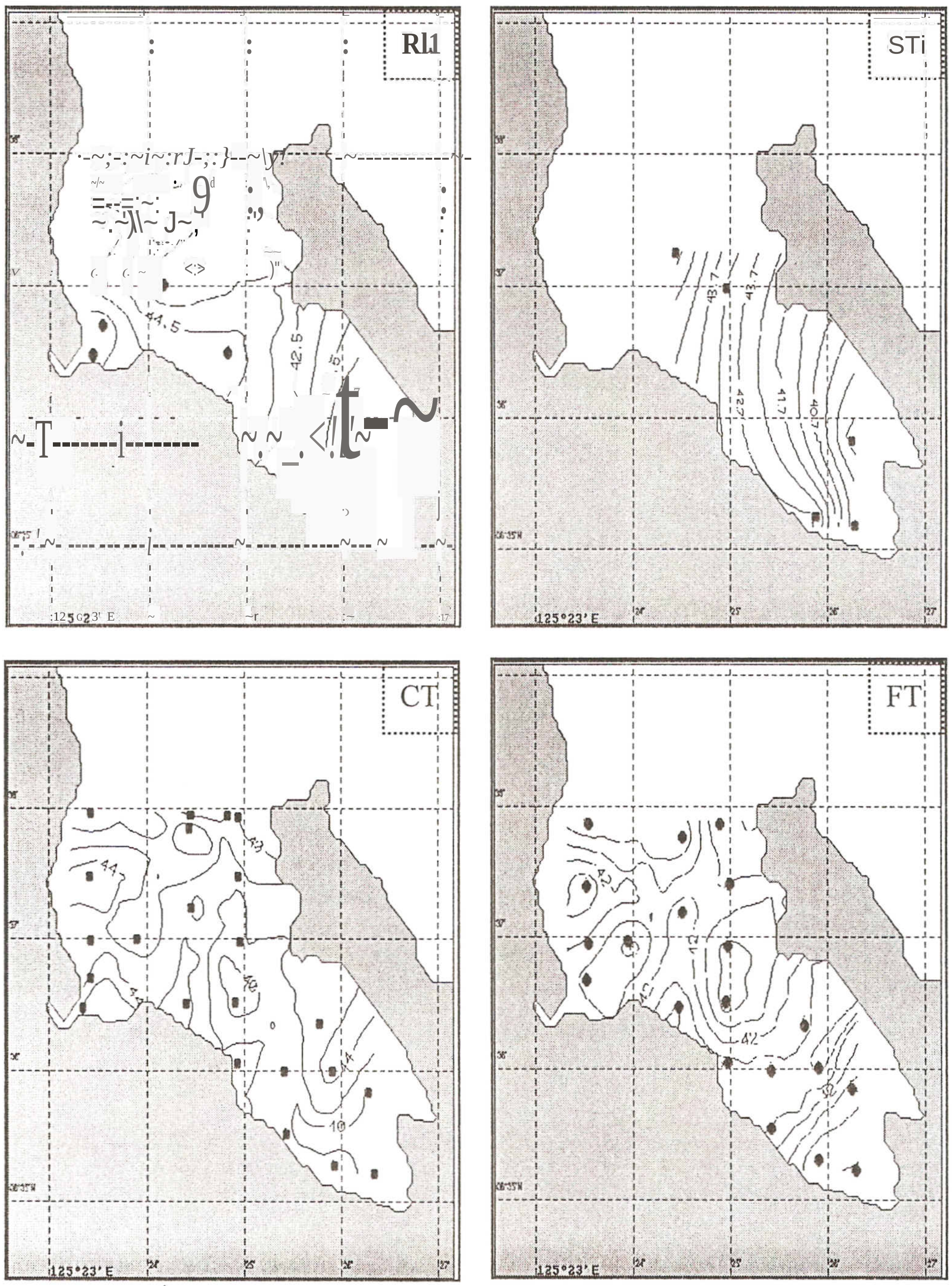


Figure 15. Dissolved Solids (ppt).
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide. For quick conversion, 1 ppt -10^3 mg/1.

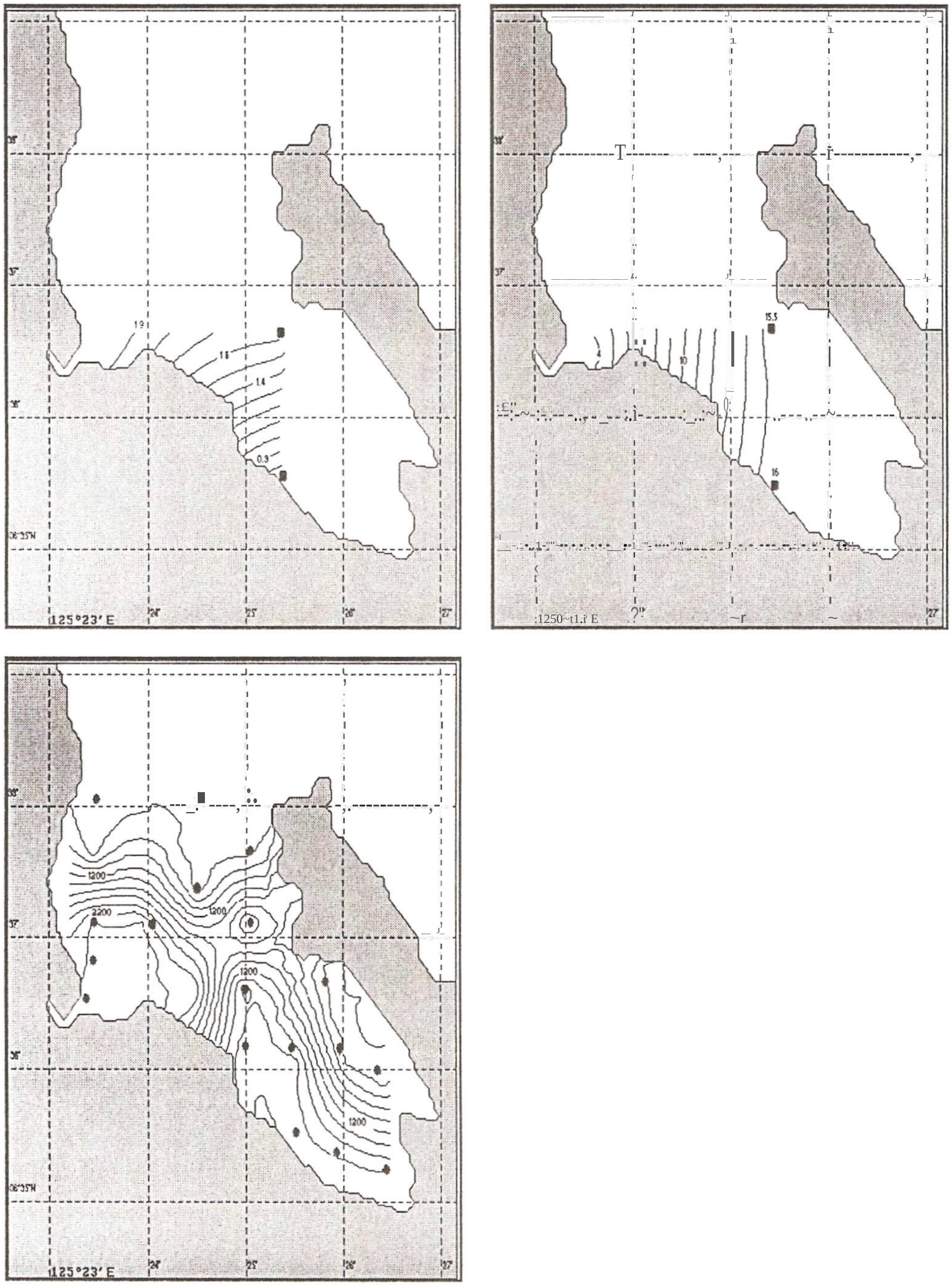


Figure 16. Settled/Settleable Solids (g).
Top-left:. Distribution in grams. Top-right:. The corresponding extrapolated set up depths in meters (right). Bottom: Extrapolated distribution in mg/m^2h. (Note: Catch area of sediment trap=128.68 cm^2 (-1.29 x 10^2 rrf). When converting into units of $[ML^{-2}T^{1}]$, the mean exposure of 63.22 hours was used.)

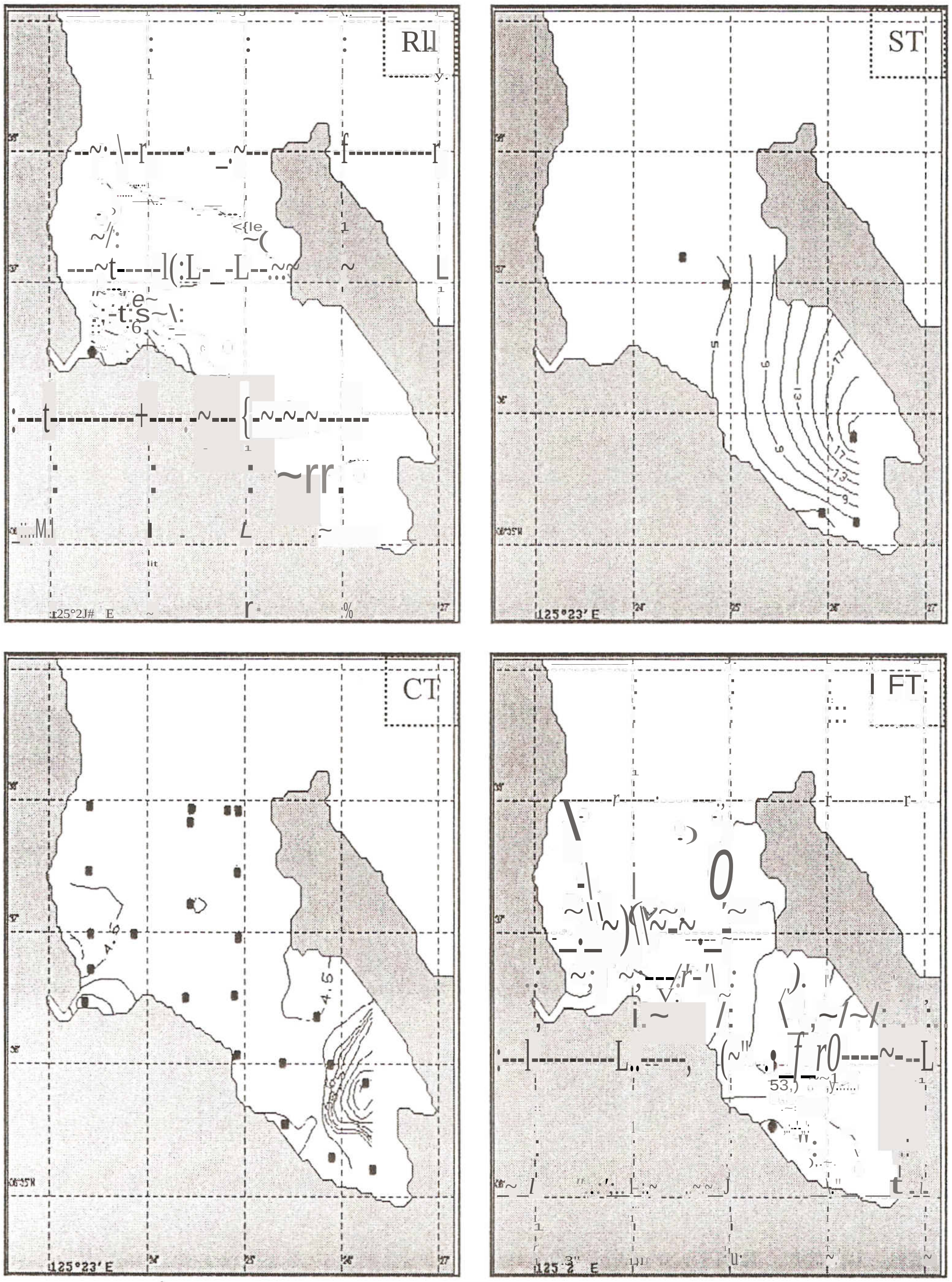


Figure 17. Turbidity (NTU).
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide.

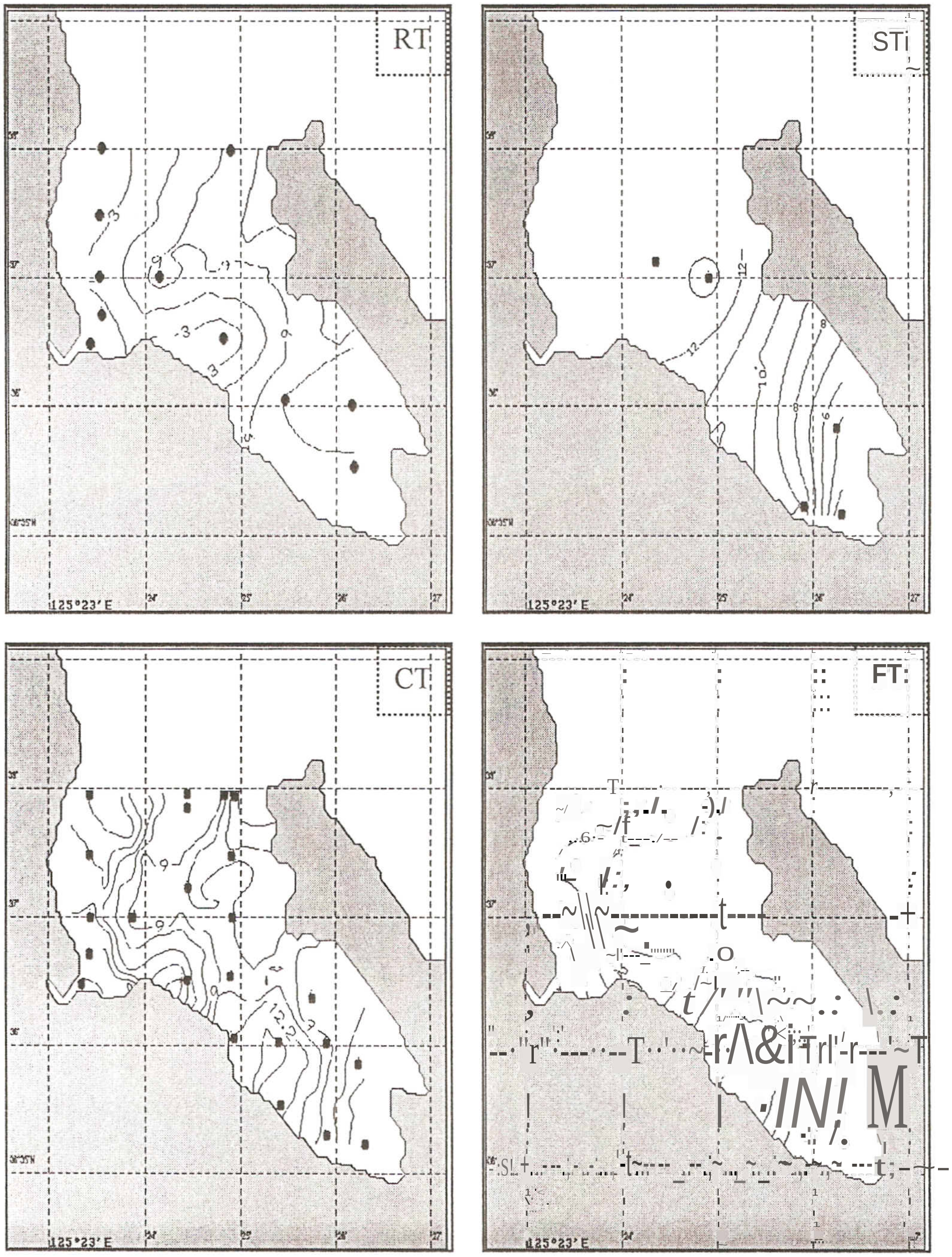


Figure 18. Transparency (m).
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide.

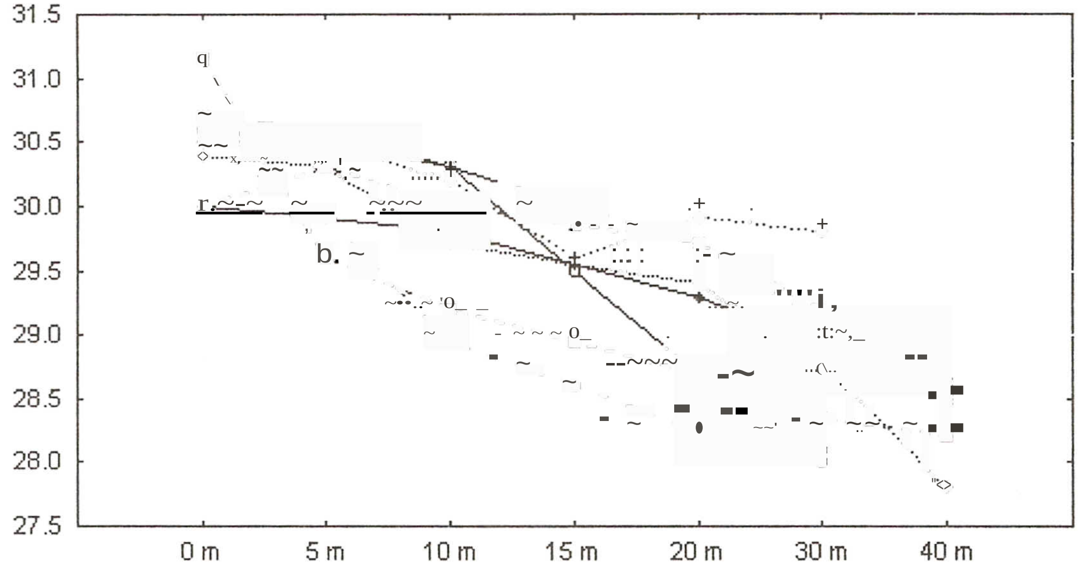


Figure 19. **Temperature Depth Profiles.**
The observed variability with depth supports the assumption of significant mixing throughout the water column.

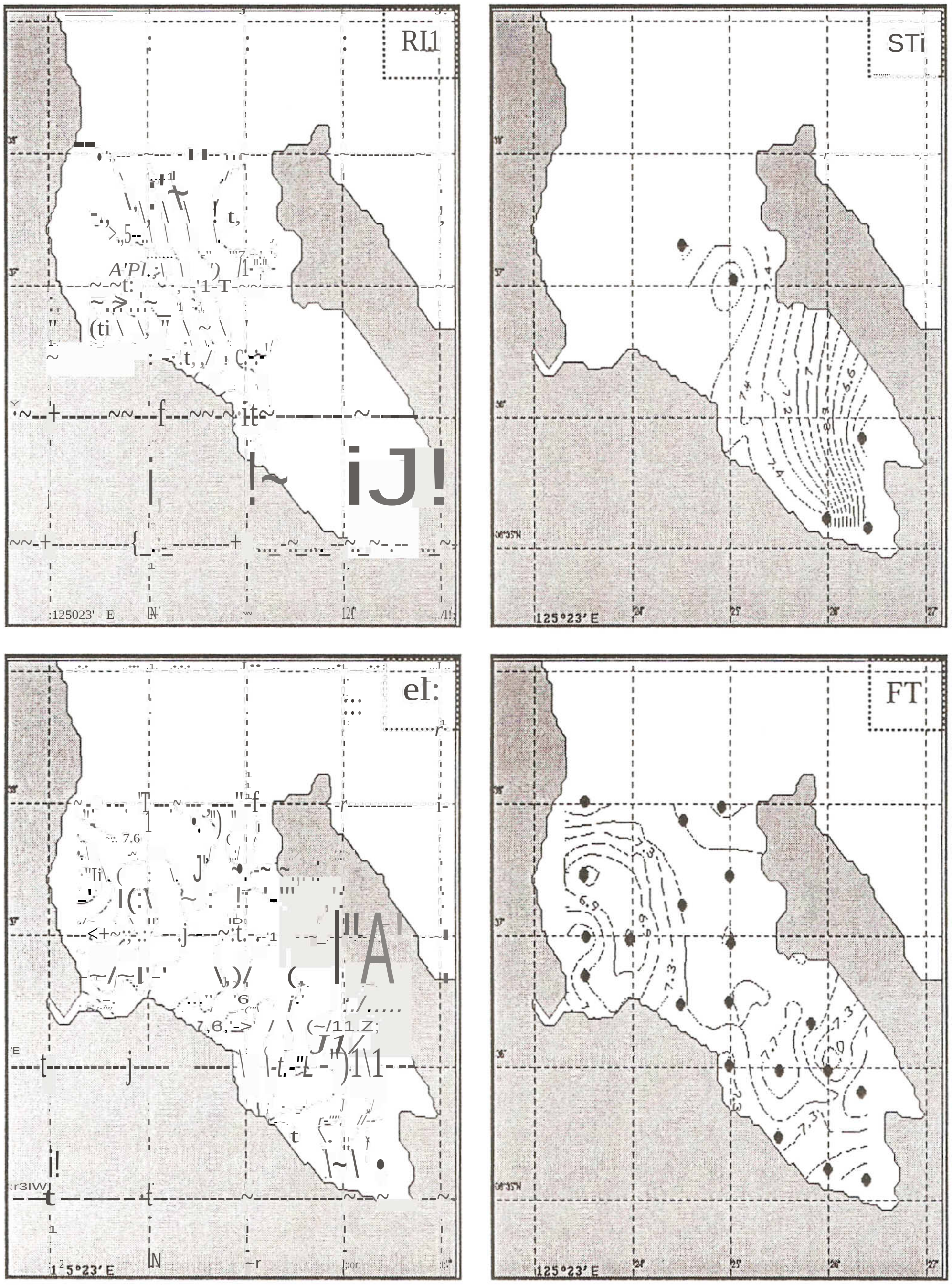


Figure 20. pH.
Clockwise from top-left: during RT, ST, FT, and CT phases of the tide.

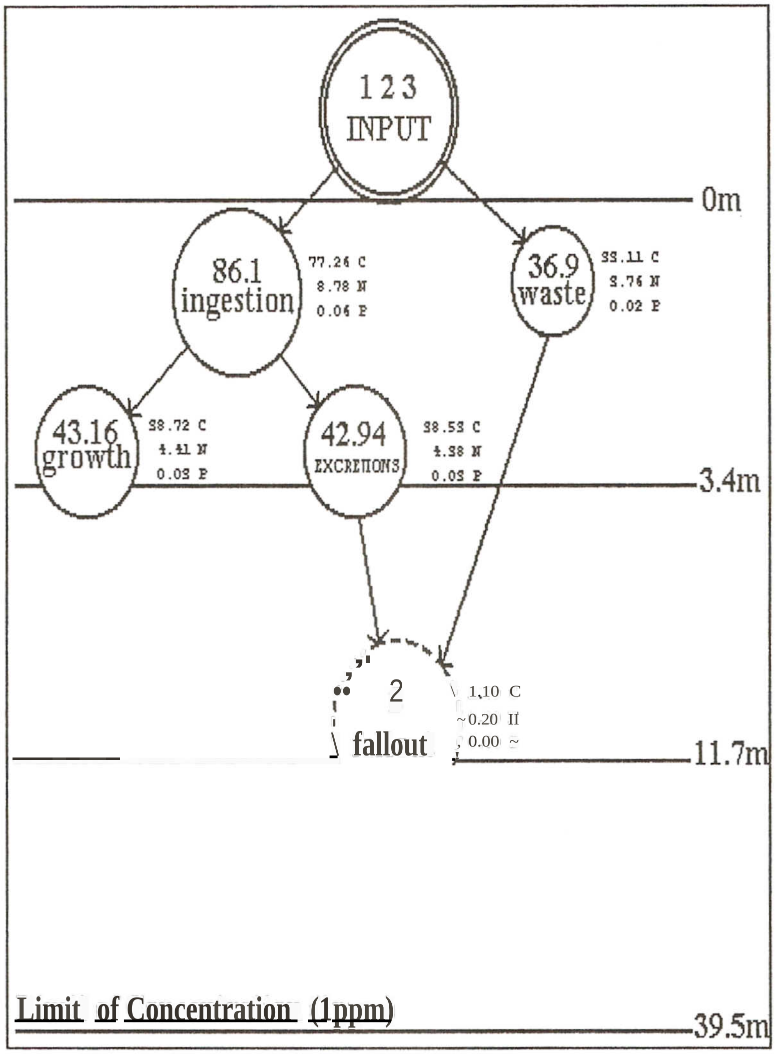


Figure 21. A Feeds Budget.
A schematic of the fate of feed input at the surface waters (data inferred from the literature). A practical depth limit corresponds to an arbitrary feed concentration of 1 ppm. This limit may vary depending on the components of the feeds and their implications.

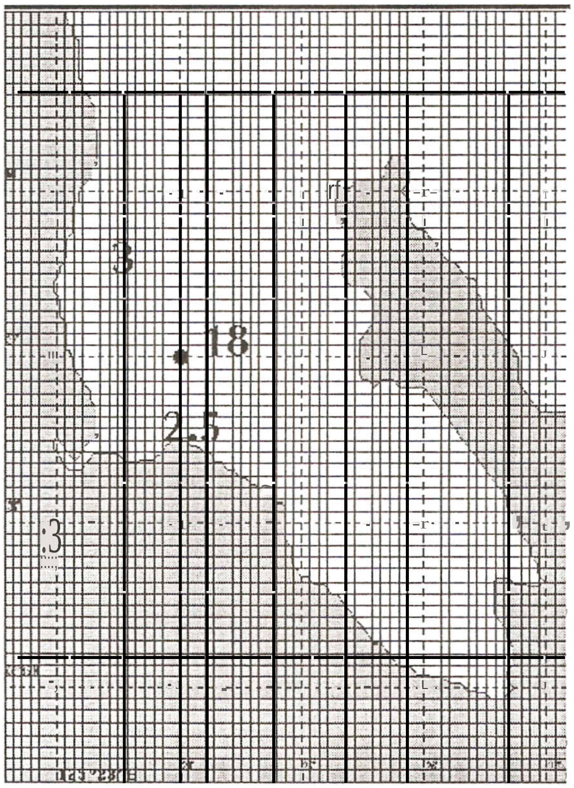


Figure 22. Gridded Domain, Malalag Bay.
The total number of grid points is 120 x 120= 14400. The so-called "nearest neighbor" interpolation technique assigns simply the nearest available value to the grid point in question. In the figure, the point in question is marked by a dot, and the nearest value that it can take is 18.

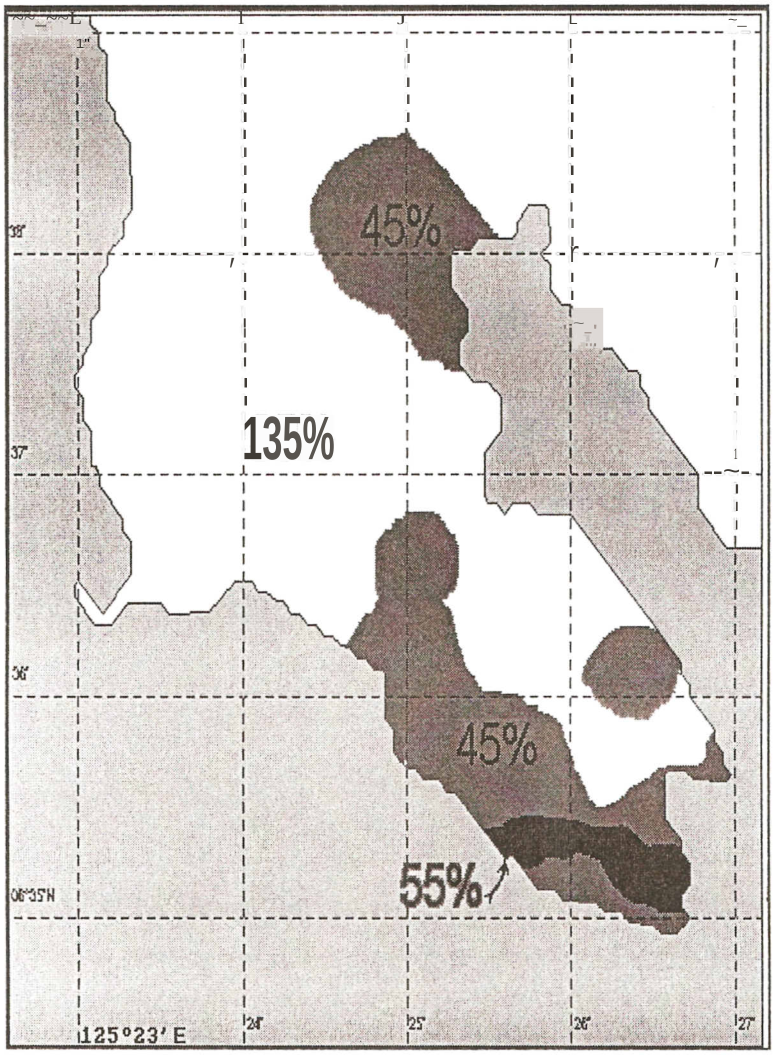


Figure 23. Suitability (%).
Also an index of the carrying capacity (CC) of a mariculture area. LOW(O-33%)-*unsuitable*, *MEDIUM(34-67%)-conditionally suitable* (supervised or regulated mariculture), and *HIGH(68-100%)-suitable.* The whole bay area is classified under **MEDIUM** suitability and, hence, permits only supervised mariculture. Nearly 2/3 of the bay is almost unsuitable for mariculture activities. See text for an alternate indicator of exceedance (E) of mariculture activities. It is simple matter to use equivalent proscriptions in terms of feeding rates, area of culture, or stocking density .

Table 4. A portion of the input file for 12 variables. The format must be followed strictly and in readable ASCII,

GLOW:;	GLAT	FHA	DO	BOD.5	PH	J	T	TUEB	;~Er
			Iilg."'f'1	Iil'J."'f'1		ppt	"C	l,mJ	Iile.J
62.000	42.000	PT	-9999.00	20..57	6.94	:35.0	30.;:iO	4.60	
76.000	41.000	PT	7.4.5	[illegible]	7.34	J.5.0	30.60	4.63	
76.000	29.0!]C1	PT	[illegible]	[illegible]	7.17	~:.5.0	3D.7el	5.40	
50.000	54.000	F.T	7.30	17.65	7.6e	35.0	:30.00	[illegible]	
23.000	.53.DOO	PT	6.03	17.65	[illegible]	3.5.0	30.10	7.53	
25.000	60.0DD	PT	6.8]	17.6.5	6.82	~:.5.0	31].10	S.43	2
2.5.000	67.000	PT	7.05	17.6.5	7.E:6	35.0	30.00	4.57	
25.000	93.000	PT	7.07	13.37	[illegible]	3.5.0	30.00	4.73	
51.000	93.0DO	PT	[illegible]	13. ~~7	7.24	3.5.0	30.00	5.10	
64.000	92.000	PT	[illegible]	[illegible]	7.19	35.0	30.00	[illegible]	
63.000	80.000	PT	[illegible]	13. :37	7.02	35.0	30.00	[illegible]	
25.DOO	80.000	PT	7.5.5	[illegible]	7.76	35.0	31.5D	4.90	
37.000	67.000	PT	7.25	17.65	7.69	35.0	30.00	4. :33	
c:9.000	42.000	IT	7.26	11.14	6.52	3.5.0	30.70	7..57	2
85.DOO	50.000	IT	7.15	11.14	7..50	35.0	30.50	4.6]	
63.0DO	..55.000	IT	7.25	1:3.:37	[illegible]	35.0	30.40	5.10	
64.000	67.000	IT	7.47	11.14	7.72	:3.5.0	]0.2.5	5.03	
51.000	73.000	IT	7.50	IJ.37	[illegible]	35.0	30.10	.5.23	
37.000	67.000	IT	[illegible]	17.65	6.60	3.5.0	30.10	5..57	2
25.000	eo.000	IT	7.46	IJ.17	6.51	35.0	29.:::5	4.73	
64.000	;::0.000	IT	7.47	13.17	[illegible]	:3.5.0	29.80	4.60	
61.000	92.000	IT	[illegible]	1:3.17	7.22	35.0	29.:::0	4.90	
51.000	90.000	IT	7.47	1:::.17	7.51	~:.5.0	30.50	.5.00	

Table 5. Bathymetry input. Values were taken from map of the study area. The three columns are: grid-x coordinate (longitude), grid-y coordinate (latitude), and the depth, either in fathom or meter.

~.14	2.11	0.00
4.29	[illegible].11	0.00
6.43	2.11	0.00
8.57	2.11	0.00
10.71	2.11	0.00
12.86	2.11	0.00
15.00	2.11	0.00
17.14	2.11	0.00
19.[illegible]9	2.11	0.00
[illegible]41	2.11	0.00
[illegible].5[illegible]	2.11	0.00
25.71	2.11	0.00
[illegible].86	2.11	0.00
30.00	2.11	0.00
32.14	2.11	0.00
34.29	2.11	0.00
36.43	2.11	0.00
38.57	2.11	0.00
40.71	2.11	0.00
42.86	2.11	0.00
45.00	2.11	0.00
47.14	2.11	0.00
49.29	2.11	0.00
51.43	2.11	0.00
53.57	2.11	0.00
55.71	2.11	0.00

Table 6. Standard Variables, Limits, and Relative Importance. The units shown are the adopted standard in this study and the ones used in the calculations.

VAR	MIN	MAX	UNIT	RelWt	REMARKS
SETTS	-9999	860	mg/m^2h	75	
SUSPS	-9999	80	mg/l	50	
DS	-9999	0.9756	ppt	20	important with rivers
TURB	-9999	3.5	NTU	40	
DO	5	9999	mg/l	50	
BOD	5	10	mg/l (5d)	65	
T	28	31	°C	50	
S	10	35	ppt	50	32 ppt- min. in open sea
pH	6	8.5		50	(no units)
NPP	828.3	9999	mgC/m^3d	65	
DISP	-9999	2.7	%	100	per settling time
					.25mm/s 39.5m
					3.5 cycles n=2604
legend:					
SETTS- settleable solids				-9999	>> no specific data
SUSPS- suspended solids				9999	>> no specific data
DS- dissolved solids					
TURB- turbidity					
DO- dissolved oxygen					
BOD- biological oxygen demand					
T- water temperature					
S- salinity					
NPP- net primary productivity					
DISP- dispersion index					

Table 7. A sample suitability output for DISP. The simple DOS edit command was used to display the values.

3	1	16.260160
4	1	16.260160
5	1	16.260160
6	1	16.260160
7	1	16.260160
8	1	16.260160
9	1	16.260160
10	1	16.260160
11	1	16.260160
12	1	16.260160
13	1	16.260160
		C:\PENCAGE\OUT\DISP
104	120	16.260160
105	120	16.260160
106	120	16.260160
107	120	16.260160
108	120	16.260160
109	120	16.260160
110	120	16.260160
111	120	16.260160
112	120	16.260160
113	120	16.260160
114	120	16.260160
115	120	16.260160

APPENDIX 1. An Executive Report

1. INTRODUCTION

Malalag Bay, an important learning area of the Coastal Resource Management Project (CRMP), resembles a small indentation of the western coastline of Davao Gulf (Figure A 1). Uncontrolled use of the bay, for instance, the congestion of fish pens and cages, had been suspected to have reached a point of environmental destruction. Thus, concern on the detrimental impact of these devices prodded CRMP to initiate an assessment of the health status of the bay. The assessment had an additional objective of packaging a simplified technology for dealing with similar problems in the country.

2. METHODS

An unsophisticated methodology was invoked. Field work was carried out to collect mainly surface measurements of important environmental parameters. Modeling on the computer was done also to assessthe dynamical character of the bay. All these procedures were aimed at answering four basic questions: 1) Is the water quality of the bay deteriorated? 2) Is the productivity potential low? 3) Does the existing mariculture (among other unstated sources) introduce a significant amount of pollutants to the bay? 4) Is the water circulation able to disperse these pollutants? The following explains briefly on the pertinent observations and analyses.

The standard procedure for distinguishing healthy from unhealthy waters uses a set of criteria prescribed, e.g. by the Department of Environment and Natural Resources (DENR). Using portable instruments, the following were measured against these criteria: turbidity (TURB), dissolved oxygen (DO), biological oxygen demand (BOD), water temperature (T), salinity (S), and pH.

To the problem of productivity potential, the net primary productivity of the bay (NPP) was determined via DO measurements. In view of mariculture, it was clarified if the bay was capable of producing (rather than consuming) extra food, in order for it to support further fish growth. To optimize expense, NPP observations were made only at representative places (below).

Certainly, the mariculture activities introduced pollutants to the water, mainly in the form of feed wastes. In fact, the amount of feeds raining down from under the pens and cages was used as an indicator of the intensity of the activities at the surface. To account for this fallout, settleable solids (SETTS) were measured comparatively at three representative sites; the pens and cages, places devoid of these devices, and the Balasinon freshwater tributary (Figure A2).These regimes are shown in Figure A3 to be covered adequately by sampling stations.

Finally, water circulation, the dominant influence on the distribution of other parameters, was measured.The ability of the water medium to cleanse itself of pollutant load was extremely important to describing the condition of the bay. For this purpose, a computerized dispersion-advection simulation (represented by the parameter DISP) was carried out utilizing (uniquely) observed currents. As a var.iable, DISP had the special advantage of quantifying the dispersive ability of any localized portion of the bay without the necessity of knowing the effects of water inflows (or outflows) and the bay's complex configuration.

The decision to declare a given portion of Malalag Bay as suitable or unsuitable for mariculture was based on a direct parameter comparison with DENR and derived standards. Table A 1 lists these standards with their limits and relative importance. DISP is given the most weight by virtue of its being the only dynamical parameter. SETTS is ranked second because of its significant use as a solid indicator of feeds wasted by mariculture. The rest of the variables are reasoned out similarly, relative to their importance to the analyses. In a plain linear combination, the weights of the parameters were used to determine a simple rating for the suitability of mariculture. Suitability was designated as LOW for values between 0-33%, MEDIUM for 34-67%, and HIGH for 68-100%.

Additional considerations to mariculture had something to do with the prohibition of activities in designated navigational lanes and critical channels, and sanctuaries.

3. RESULTS

The interrelation amongst different parameters is schematized in Figure A4. The diagram shows DO at a convenient focal point of the complex interactions ranging from atmosphere input to utilization in the bottom sediments. The contents of these sediments may reflect also the amount of SETTS generated by the cage culture. BOD (a DO derivative) indicates the oxidation requirement of organic matter in the water column. NPP is indicative of the balance between plant production and respiration mainly by animals. Likewise, the other water quality parameters (OS, TURB, SUSPS, pH, T, and 5) are jointly associated with the existing biochemical interactions and inputs from tributaries (rivers or seepage). Overall, the redistribution of parameters is governed overwhelmingly by the water movement (DISP). The prescribed values in Table A1 characterize jointly a healthy environment. .

The suitability map of Figure A5 shows a rather dismal scenario for the bay- the whole bay area is found only as conditionally suitable (MEDIUM) for culture. Worse, nearly 2/3 of the bay is close to the limit of unsuitability (LOW). Further complications to these results are: the proscriptions to mariculture usage of the bay's entrance, the sanctuary, and marginal areas shallower than, say, 2 m (the tidal range).

It is conceivable that mariculture had been carried out excessively to the point of deteriorating the environment.. A more direct finding based on SETIS alone indicates that the intensity of fish culture in the bay had exceeded its limits by about 2.5 times. This result is almost exactly corroborated by the suitability rating of about 40%, averaged spatially from the above suitability plot.. The physical factor that may explain this predicament is the peculiar circulation which does not seem to favor the outflow of water from the bay (Figure A6).

It is important to note that the findings of these study are valid for the northeast monsoonal period of observation, simplified by the virtual absence of tributaries to the bay due to the prolonged dry spell by the El Nino.

The main procedures in this study are condensed in a simple computer software, for ease of application by LGUs or CRMs to similar areas of interest.

4. CONCLUSIONS

This study succeeded in determining the health status of Malalag Bay as conditionally suitable for mariculture (pens and cages) activities. The analyses indicated that the bay exceeded its environmental limits by about 2.5 times, such that the on-going activities must be regulated accordingly.The method of assessment is available as a software.

5. RECOMMENDATIONS

An information campaign on the predicament of Malalag Bay is in order. The use of the bay mustbe be regulated, specifically by reducing the current mariculture activities by some 2.5 times. Locally-specific implementation of this recommendation may be guided by the suitability map.

It is conceivable that environmental conditions may change during the opposite (southwest) monsoon and when the tributaries are relatively active. Under this condition, again, the relevant field information must be gathered and integrated to the current database. A dynamic management of the bay is encouraged with proper reference to an evolving database and socio-economic informationO

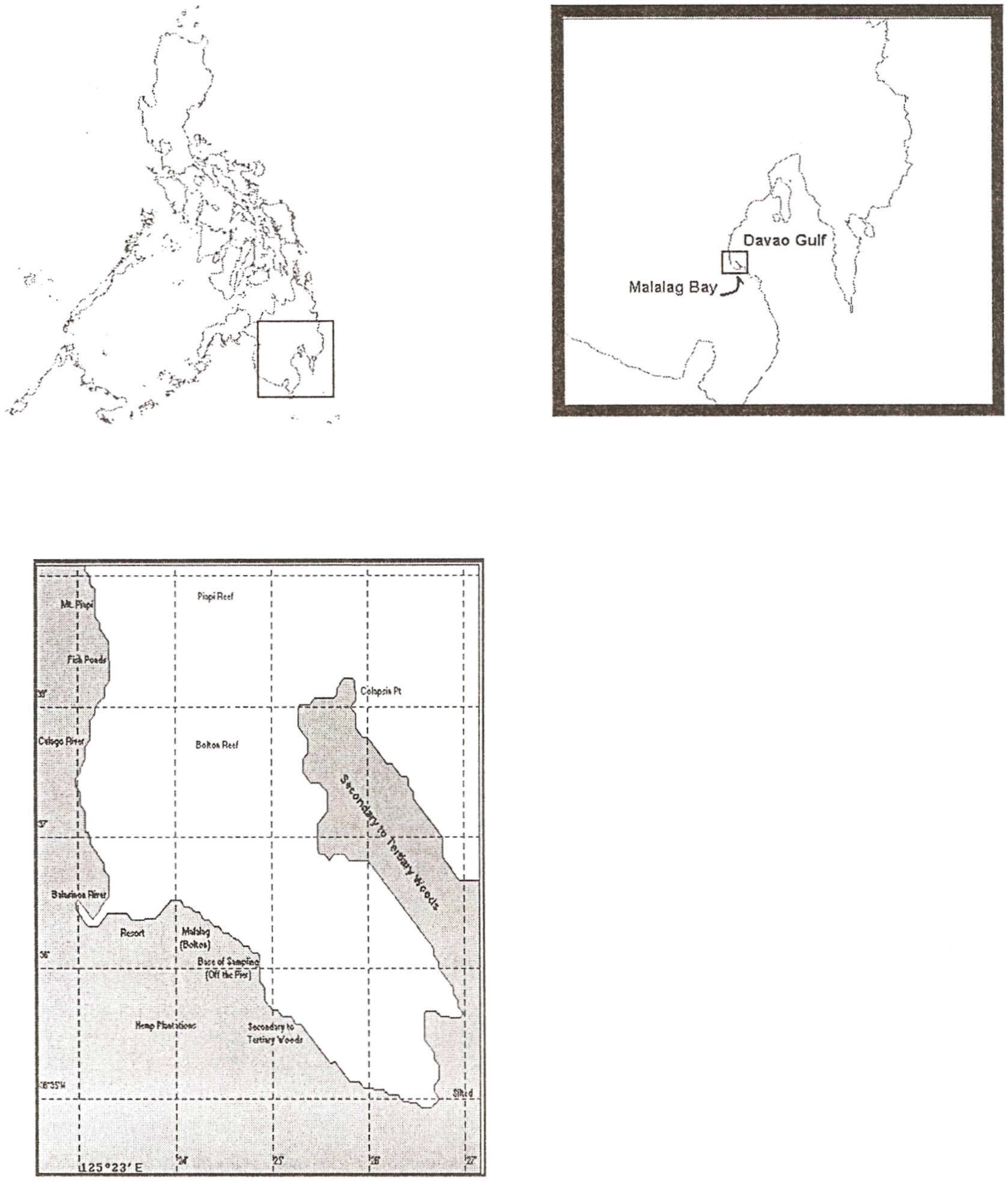


Figure A1. Malalag Bay, Davao del Sur.
Location of the study area as sourced from **NAMRIA** Chart No.4656 plus some updated features.

Figure A2. **Fish Culture Gears.**
The totality of mariculture structures in Malalag Bay (21 fish pens, 732 cages, and 13 corrals), including the arbitrarily designated sanctuary (rectangular area- based on municipal ordinance, Diel 1983; diamond area- drawn from the positions of buoys). Symbols used are H for pens, square for cages, and caret for corrals. All structures are scaled approximately to their actual sizes and respective locations.

TABLE 1. Standard parameters, limits, and relative importance.

VAR	MIN	MAX	UNIT	RelWt	REMARKS
SETTS	-9999	860	mg/m^2h	75	
SUSPS	-9999	80	mg/l	50	
DS	-9999	0.9756	ppt	20	important with rivers
TURB	-9999	3.5	NTU	40	
DO	5	9999	mg/l	50	
BOD	5	10	mg/l (5d)	65	
T	28	31	°C	50	
S	10	35	ppt	50	32 ppt- min. in open sea
pH	6	8.5		50	(no units)
NPP	828.3	9999	mgC/m^3d	65	
DISP	-9999	2.7	per cent	100	per settling time
					.25mm/s 39.5m
					3.5 cycles n=2604
legend:					
SETTS- settleable solids				-9999	>> no specific data
SUSPS- suspended solids				9999	>> no specific data
DS- dissolved solids					
TURB- turbidity					
DO- dissolved oxygen					
BOD- biological oxygen demand					
T- water temperature					
S- salinity					
NPP- net primary productivity					
DISP- dispersion index					

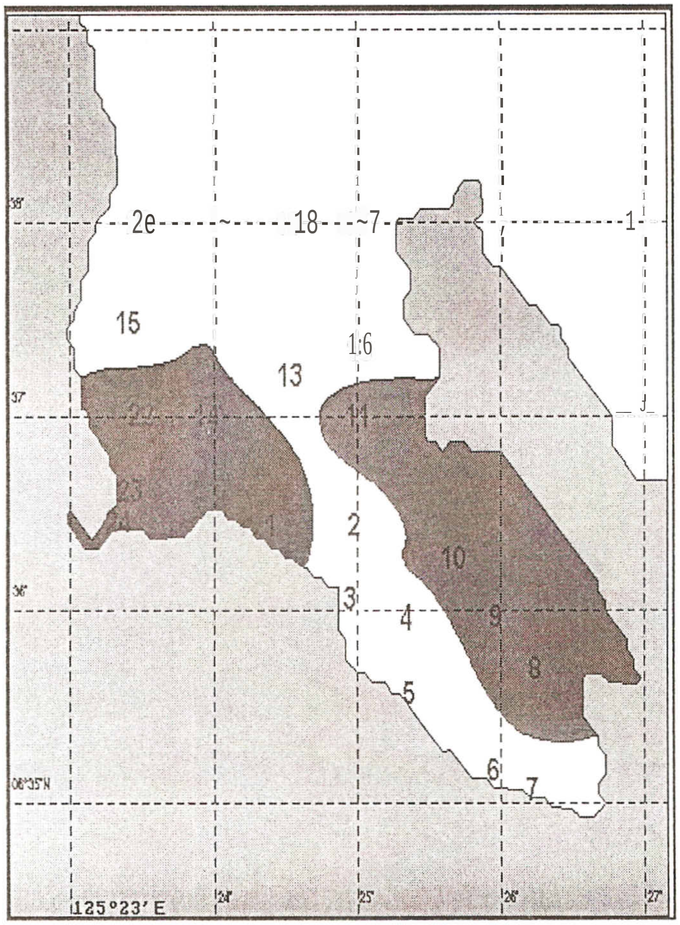


Figure A3. **The three sampling regimes.**
1) regime of pens and cages, represented by Stations 8-11, 2) regime devoid of gears, represented by Stations 2-7, 13, 15-18, and 20, and 3) regime of Balasinon tributary; represented by Stations 1,14,22-24. The total number of sampling stations is 21.

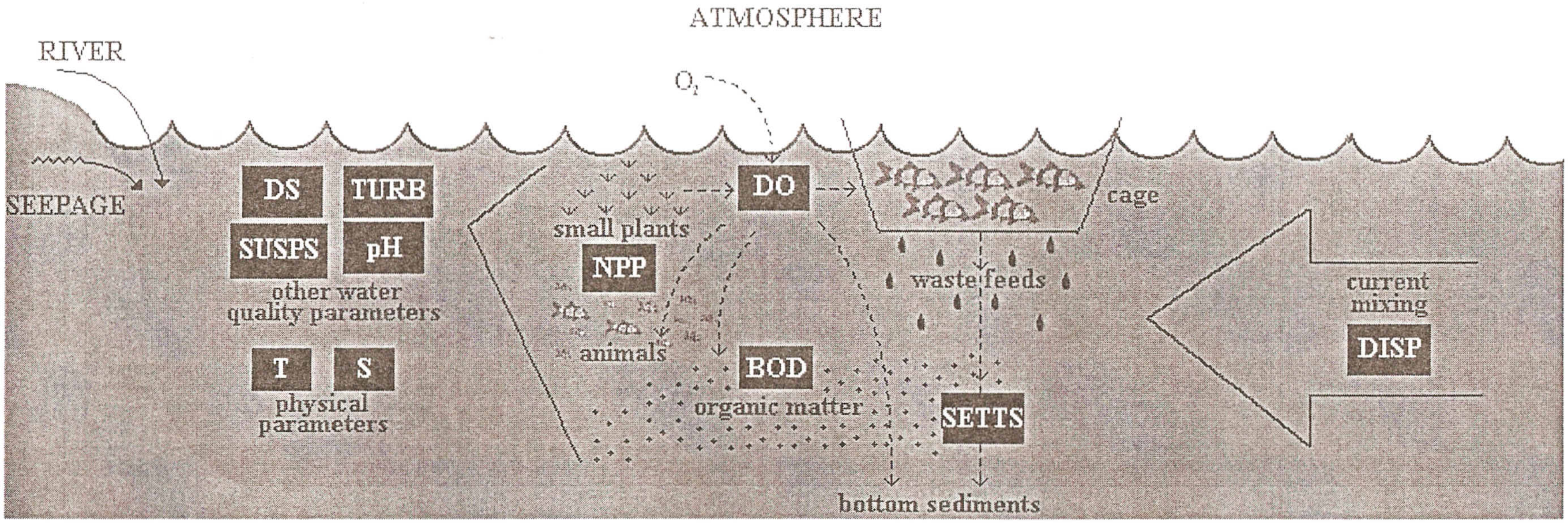


Figure A4. A schematic of the association of parameters.
OS- dissolved solids, SUSPS- suspended solids, TURB- turbidity, T- temperature, S- salinity, NPP- net primary productivity, 00- dissolved oxygen, BOO- biological oxygen demand, SETTS- settleable solids, and OISP- dispersion.

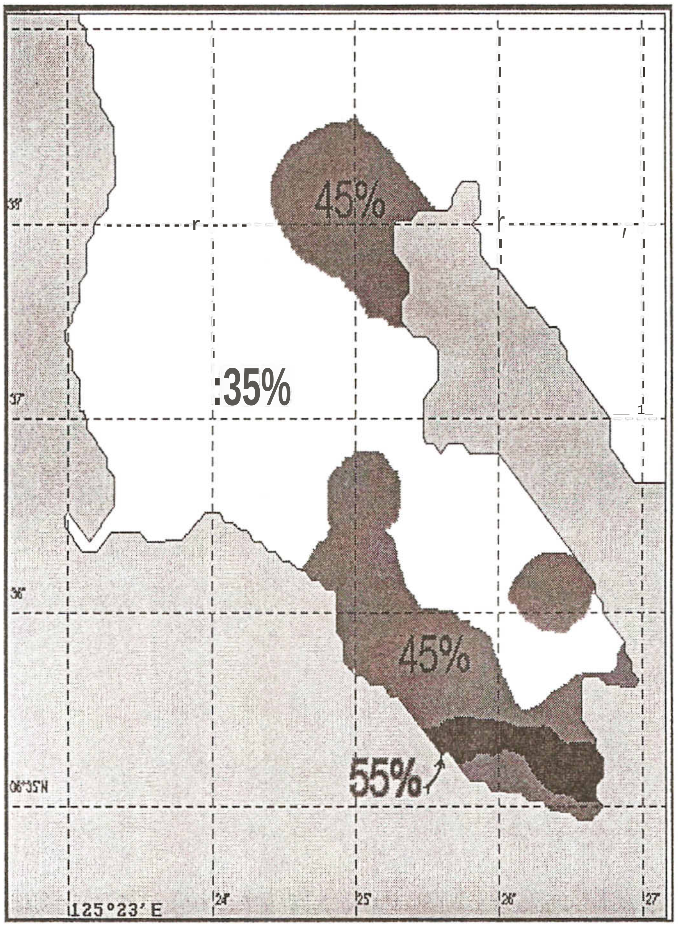


Figure AS. **Suitability for Mariculture** (%).
LOW(O-33%)-unsuitable, MEDIUM(34-67%)-conditionally suitable (supervised or regulated mariculture), and HIGH(68-100%)-suitable. The whole bay area is classified under MEDIUM suitability and, hence, allows only supervised mariculture activities. Nearly 2/3 of the bay is almost unsuitable for these activities .

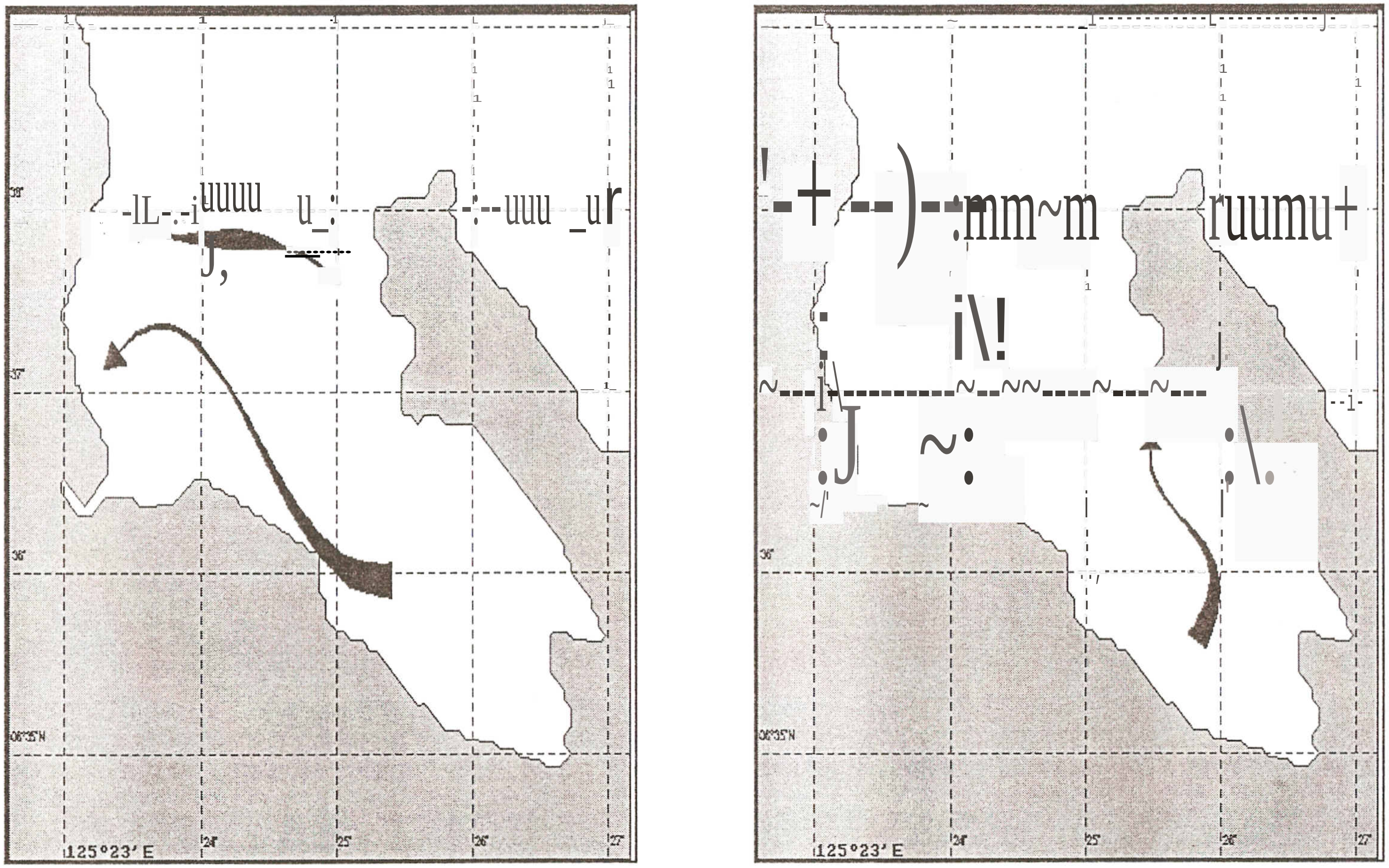


Figure AG. Schematic of the circulation in Malalag Bay.
Left: during the rising tide. Right: during the falling tide.

APPENDIX 2. Dynamic, Data-based Interaction (001)- The Concept

In a broader sense, 001 suits best the model that is being conceptualized in this study. However, because the idea is rudimentary and developing, it is appropriate to mention only the general framework of this approach to environmental modeling and management..

DDI rests on two fundamental principles:

i) Concrete databasing is prerequisite to management..

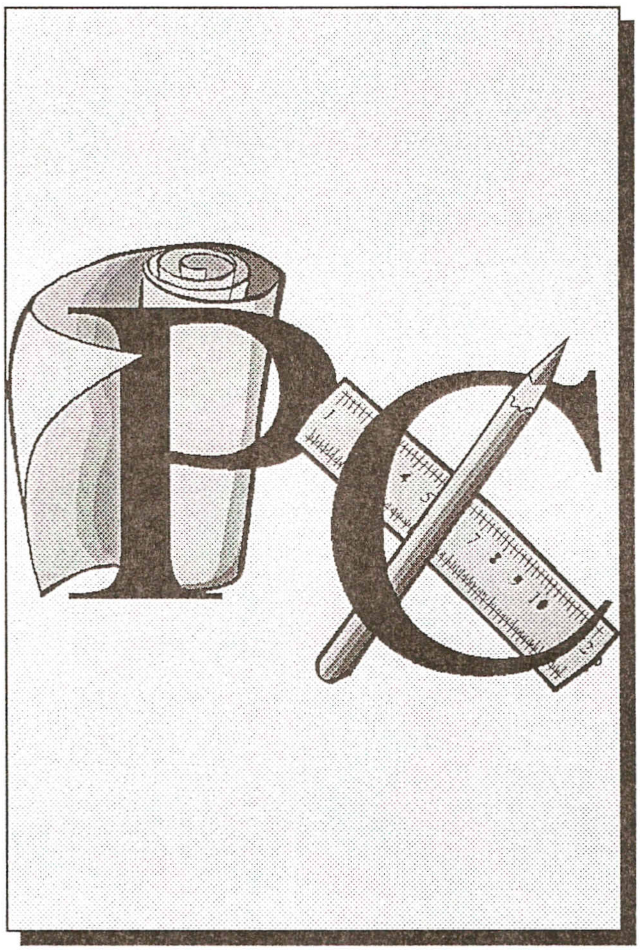
Obviously, it is nonsensical to indulge in management without facts. Further, since the task of management is already complex, abstraction in the input data must be minimized in order to come up with concrete strategies. Hand-waving policies are products of abstraction and are unlikely to be amenable to systematic analysis and use. Concreteness necessarily implies also representativeness because it would be difficult to piece out an integral picture from defective, inaccurate, or inadequate data. Consequently, data gathered must reflect the entirety of measurements, surveys, and community profile (as in CB management)- all of which must be in a quantifiable form possible.

ii) Environmental management is a dynamic interactive process.

The dynamic character of the environment is a constant complication to human attempt at under-standing and fortelling its processes. In view of this, a persevering manager cannot remain invariant, especially with his strategies. He must interact continuously by updating his database and ensuing strategies. In doing this, he maximizes the utility of concurrent data while improving consistently the ability of his growing database to project trends and recurring phenomena. Ultimately, through this responsible interaction, his shaky task of prediction may become well-founded.

A workable 001 prototype is desired of this study. Particularly, because the present model assimilates observations, the model is expected to evolve with the quality and quantity of the database. It is desired that this initiates interactive dynamic management.. For instance, additional observations of the monsoons will not only trim model assumptions but, if contrasting monsoons are involved, encourage the manager to differentiate management approach by monsoon seasons. In turn, the manager may redirect subsequent sampling protocols in updating his database. Iteration of this procedure will benefit the model. Technology exists on knowledge acquisition, which can be availed to develop knowledge-based expert systems for this purpose. For instance, a simple but seminal technology has been developed to mine information from the database generated by the Fisheries Sector Program of the Department of Agriculture (Projimo 1997)[1].

1Projimo, V. 1997. Processing of FSPOceanographic Data. M.S. Thesis, University of the Philippines in the Visayas, Miagao, Iloilo. (in progress)


PC

APPENDIX 3. P&C Easy Manual

This short manual simplifies the setup and operation of Pens & Cages version 98-1 a (P&C), a handly PC software intended originally as guide to deploying fish pens and cages. P&C is a made-simple, low-technology tool for the non-technical personnel.. Mainly, the software computes for SUITABILITY, the parameter used to characterize the "carrying capacity" or "health" of a culture area and quantify the spatial and/or temporal limits of deployment of fish pens and cages or similar devices. The limits are based on generally accepted ranges for the aquatic environment. . However, final decision as to the choice and mode of gear deployment is left with the user, who is encouraged to utilized "best" judgement in exploiting the numbers generated by the software.

This documentation is divided into two sections, describing the setup and operation of P&C, respectively. After reading these sections, the user shall not find difficulty in running the sample case provided.

1. SETUP

P&C comes with this abridged manual and 1-3.5" diskette (or 1 CD) containing the program, configuration, and instruction files. The following are the installation requirements:

1.1. Minimum Requirements

Processor: 486-DX4-100MHz, IBM-compatible PC, Pentium II series preferable
Memory: 8 MB
Platform: Windows 95 version of DOS (version 7)
Disks: 1.44 MB 3.5" FD, ~ 540 MB HD
Monitor: color monitor, VGNSVGA
Optional: CD drive; Surfer Golden Software, Inc., CAP screen capture utility

1.2. Installation

Lessthan 1 MB of disk space is required by the software (607.021 KB to be exact). However, some 80 MB hard disk space must be reserved because the program generates this much amount of temporary data. Disk 1 contains 21 files (1280 KB) including setup.com,which initiates the downloading. The process is interactive and simple to follow. Simply set location at root directory of your default C-drive and type at the prompt A:setup. Note that the floppy drive used is A- not B. Upon completion of the process, the directory is set at c:\> pencage. Using the simple DOS edit command, view *readme.txt*. for additional instructions.

1.3. File Structure

The installation creates the following structure in C-root directory. The main directory is c:\>pencage. It should contain 24 files and 7 sub-directories. Some files or directories are hidden, purposedly to avoid accidental tampering.

c:\ > pencage	parent directory
pnc.com	main batch job to process raw data and obtain all results
pencag.exe	plotting routine to view results
command.com	DOS facility in Windows 95; external to the software
cap.exe	a screen capture utility, @Copyright 1987-90 by Inner Media, Inc., Hollis,NH 03049 and 1988/1990 by Software Publication Corp; external to the software
gmouse.com	a computer mouse interface, @Copyright 1988-95 by KYE Systems Corporation; external to the software
egavga.bgi	a graphical interface
goth.chr,litt.chr	character fonts

c:\ >pencage\in	input directory for raw data; sample files may serve as
bathy.raw	raw bathymetry data
tabvar.raw	a table of raw val ues of 12 variables

c:\ >pencage\pars	contains all input parameters
hilo.lo, hilo.hi, and hilo.inp	low and high tide parameters
tdetyp.inp	parameter for diurnal (1) or semi-diurnal (2) tide
uv.inp	parameter for processing velocity components
conci.dat	concentration data
depth.uni	unit of depth, meter or fathom
maxmin.lo, maxmin.la	minimum and maximum geographic coordinates

c:\ > pencage\progs	contains all 12 executable routines of the software
rd10var.exe	reads in and formats raw data
rdsepby.exe	pre-processes bathymetry
xconuv.exe	pre-processes current data
xintextO.exe	processes bathymetry
xintext.exe	processes altogether 12 variables
xstat.exe	computes averages
xxmixuv.exe	mixes current components
zbinuv.exe	simulates the current field
zdisp.exe	calculates for dispersion
zsuitab.exe	obtains suitability, first portion
zsuitabb.exe	obtai ns suitabi lity, second portion
zsuitabc.exe	obtains suitability, third portion

c:\ >pencage\out	contains all final outputs: 12 *.vat and 1*.flg files

c:\ > pe!1cage\sa.ved	keeps duplicate copies of templates and optional files
cap.exe	a screen capture utility, @Copyright 1987-90 by Inner Media, Inc., Hollis,NH 03049 and 1988/1990 by Software Publication Corp; external to the software
command.com	DOS facility in Windows 95; external to the software
gmouse.com	a computer mouse interface, @Copyright 1988-95 by KYE Systems Corporation; external to the software
savdat.com	utility to recover original sample data templates
bathy.raw	raw bathymetry data
tabvar.raw	a table of raw values of 12 variables

c:\ > pencage\work	the working directory; all files are treated as temporary
readme.txt	ASCII file containing last minute instructions

savdat.com	utility to recover original sample data templates
bathy.raw	raw bathymetry data- sample
tabvar.raw	a table of raw values of 12 variables- sample

c:\>pencage\store	storage area for user files

2. OPERATION

2.1. Sample Run

It is best to make a sample run to have a feel of what the software does. Sample inputs, derived from the Malalag Project, are provided already for this purpose- they are used also as templates. After installation just type pne to run the processing program (Section 2.2). Afterwards, type peneag to plot the results (Section 2.4). The test run will determine also whether or not your hardware is properly set up or has incompatibilities with the software routines. Incompatibilities due to meager memory and slow processor has been encountered during the testing of the software.

2.2. Pre-processing

After a sample run, the user must prepare to run his own data. The pre-processing of input observations and parameters must be done at the working directory designated as c:\>peneage\work.. It is imperative that the DOS facility of Windows 95 is used. A DOS screen must be opened, either in full-screen or re-sized DOS mode, in carrying out the following procedure.

Use the DOS editor to edit the only two input files to the processing program: *Bathy.raw* is the template file for the raw depth observations (in fathoms, from NAMRIA chart), which must be coded manually in three columns, corresponding to the two coordinates (grid coordinates from 1 t0120) and the depths themselves. *Tabvar.raw* is the table template for 12 variables observed on the field. Follow the formats of the sample files and exercise extra caution not to make deviations. Copy the edited files to c:\peneage\in, overwriting the files there of the same names.

In case of mistakes in coding or if the template files are garbled, just type savdat in the same directory and new templates come up. Be careful as this will automatically delete the input files, replacing them with new templates.

There are a few parameters that need to be checked prior to running properly the processing program. These are found in c:\peneage\pars. Edit *tdetyp.inp* and change the tide type of your study area accordingly as 1- diurnal or 2- semi-diurnal.. The best place to look for this information for your locality is NAMRIA's Tide and Current Tables, which is updated yearly. The value in *depth.uni* must be set to "1" if your input (raw) bathymetry is already in meters or "2" if in fathoms (the usual units read off from NAMRIA charts). For conversion of grid to real geographic coordinates, the files *maxmin./o* and *m·axmin./a* must be edited with the actual map values. Simply replace the minimum and maximum longitude and latitude values in these files. The conversion routine is called *gridcoor.exe.* It can be ran separately to do the automatic conversions. The routine may be used at anytime for this purpose.

2.3. Processing

As long as the inputs are properly set up, processing is simplest. Just type pne at the DOS prompt to run the long (relatively speaking) batch file, *pnc.com,* and watch the screen for about 16-25 min (depending on processor speed). A PENTIUM II 233MHz (recommended) will finish the job in only about 16 min. The lengthy procedure will produce output files in c:\peneage\out.. Do not touch these files.

2.4. Graphical Plot

Viewing the results is a little tricky because of current problems with the plotting routine. The computer must be placed in EXCLUSIVE DOS mode. One switches to this mode from the usual

Windows 95 DOS window (protected mode) by clicking on the "advanced" properties of the DOS window and selecting exclusive DOS usage. In this mode, Windows 95 closes itself giving way to DOS, which now runs necessary on a full-screen mode. Once this particular DOS mode is readied, just type pencag to run the plotting program called *pencag.exe*. Pencag may be run repeatedly to re-examine the results. (Note: The computer will hang if plotting is made to run in protected DOS mode, i.e. when Windows 95 still is running.)

If you intend to obtain hard copies of plots, run *cap.exe* prior to running *pencag.exe*. The screen capture utility will save the screen image as *.pcx file, which can be then be printed or manipulated using the Paintbrush utility of Windows.

2.5. Re-runs

With new set of observations, simply repeat the preceeding sequence of procedures. Old output files are erased with every batch job. To save old results, store them elsewhere, for safekeeping. The directory c:\pencage\store may be used for this purpose.

The software displays a generous amount of instructions to make its operation self-explanatory. However, utmost care must be taken not to modify any other files, unless asked specifically to do so. Some subdirectories are not to be used and are hidden from view for protection. To view them, just type **dir** *fw* fa at parent directory, c:\>pencage. Actually, there is no reason why a user must do this.

Software Disclaimer and Credit:

P&C is a secured software and will install only once for authorized users. Copying, improper use of the routines, and unpredictable results, and ensuing damages are outside the responsibility of the author, CRPM, or USAID. Problems and suggestions may be refered to: Rex Balena, POB 249, Iloilo City, PHILIPPINES 5000; tel: (63)-33-3158378 telefax: (63)-33-[illegible]

APPENDIX 4. Malalag Bay Database

(tabvar.raw, comes with P&C Software also, 1 diskette)