Environmental and production survey methodology to estimate severity and extent of aquaculture impact in three areas of the Philippines

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ABSTRACT

The project "Environmental Monitoring and Modelling of Aquaculture in the Philippines" known as EMMA, was undertaken by the National Integrated Fisheries Technology Development Centre (NIFTDC) of the Bureau of Fisheries and Aquatic Resources (BFAR) and Akvaplan-niva AS of Tromsø, Norway. The project was funded by the Norwegian Agency for Development Cooperation (NORAD). This project tested survey equipment for the monitoring of aquaculture impact to the water column and sediment. Baseline surveys were undertaken as the goal of the study was to develop suitable aquaculture monitoring techniques and adapt predictive models to assist in identifying risk areas for aquaculture and allow planned development of sustainable aquaculture. Three different locations were chosen as case studies - Bolinao, Pangasinan (marine site), Dagupan (brackish water site), and Taal Lake (freshwater site). Production surveys were also undertaken to estimate production and nutrient outputs to the water bodies in order to be able to link aquaculture production with severity and extent of impacts. Different methodologies for the estimation of production were tested to find a cost effective and accurate methodology.

INTRODUCTION

Background and scope of the investigations

Under the project 'Environmental Monitoring and Modelling of Aquaculture in Risk Areas of the Philippines" (EMMA), environmental surveys were undertaken in marine waters of Bolinao, in the brackishwater area off Dagupan, and in freshwater Taal Lake. Seven field surveys were carried out from April 2005 to April 2006. This paper describes the field investigations that were carried out and the initial findings on the observed environmental impacts.

The main goal of the investigation was to determine the extent of detectable impact of fish farming activities to the local environment and to train the users in using the donated survey equipment and in adapting the survey methodologies. The environmental conditions in the different areas were described using sediment and water quality parameters. These data, together with hydrographical and water current measurement and information on local bottom topography, can be used as basis for making recommendations to mitigate impact in the aquaculture areas (Fernandes et al. 2001).

General environmental issues related to aquaculture

The spatial extent and level of local environmental impact caused by a fish farm is determined by natural conditions, i.e., bottom topography, sediments and currents, in combination with the size of fish production and operational practices. A major factor in preserving environmental quality is an optimal location and operation of the farm, conforming to the existing environmental conditions.

Organic enrichment in the sediments is one of the most significant environmental effects associated with fish farming. The primary causes are wasted food pellets and fish excrement. In areas with water currents that are insufficient to remove or spread these material over a larger area, organic material may accumulate on the sea floor or within the vicinity of fish farms. Consequently, there will be a build up of nutrients which will lead to eutrophication and possibly algal blooms.

Bacterial decomposition may lead to anoxic conditions in the sediments and overlying water and to the formation of methane (CH_4) and hydrogen sulphide (H_2S) gas. Both low oxygen concentrations and the presence of methane and hydrogen sulfide have detrimental effects, e.g., reduced growth rates, increased disease outbreaks, etc. on fish in the cages within and near the impacted areas. Under extreme conditions, anoxic water and toxic gases may even cause fish mortality and algal blooms may develop.

ENVIRONMENTAL SURVEY

The most important parameters in environmental monitoring and modeling are bathymetry (depth recordings) of the area, tidal range, current speed, direction and dispersion, physical parameters (temperature, turbidity, salinity and oxygen profile through the water column), water quality (chlorophyll, phosphorous, nitrite, ammonia), sediment parameters (biological and chemical) and weather data (wind direction, speed, temperature).

Bathymetry

Detailed knowledge about the bathymetry in an area is vital information for modeling the water exchange in an area. For all the investigated areas, there existed maps with some depth recordings. However, the resolution (number of recordings) was not good enough for the modeling. Therefore a Garmin echo-sounder which contains a GPS and a chart plotter (GPSmap 178C sounder) was set up on one of the BFAR boats so that we could collect more depth readings from the areas. This setup measures and stores water depth and tracks automatically tagged with the date and time of use, as well as water temperature. This setup is part of the equipment that was donated to BFAR for their use in future projects. All the collected data were used for the modeling.

Current meters

Information about the currents (speed, direction, volume) in an area is also vital for modeling the water exchange, which in turn give information about how often fresh oxygenated water are coming in to an area, how the waste from the aquaculture activity is dispersed, etc.

MINI current meters (model SD-6000) were used in the first survey. This is a compact vector averaging current meter with memory capacity for up to 6,000 combined data sets of current speed, direction and temperature. For the second and third field surveys, the new current meters, RCM 9 LW from Aanderaa in Norway, were used (Fig. 1).

The RCM 9 LW (Light Weight) utilizes the well-known Doppler Shift principle as basis for its measurements. Four transducers transmit short pulses (pings) of acoustic energy along narrow beams. The same transducers receive backscattered signals from scatters that are present in the beams, which are used for the calculation of current speed and direction. The scattering particles are normally plankton, gas bubbles, organisms, and particles stemming from man-made activity.

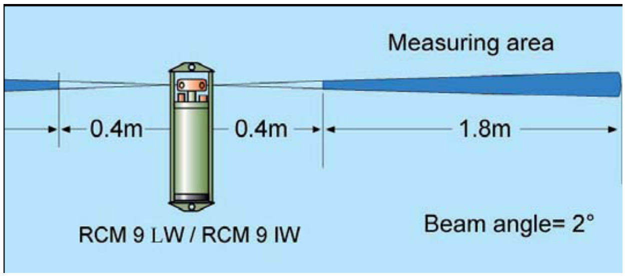

Figure 1. Illustration of the measuring area for the RCM 9 LW current meter

Two of these current meters have additional sensors to measure conductivity, turbidity, oxygen, and pressure (depth). The current meters were programmed to measure temperature, current-speed and current-direction every 5 minutes. Ideally, the current meters should be recording between 2 and 6 weeks per station to get a really good picture of the current behaviour in an area. However due to time limitation, most of the current meters were deployed for approximately 24 hours only at each station. Most of the investigated areas were relatively shallow so only one current meter was used at each station. For most of the stations, the current meters were placed in the middle of the water column. For areas with 15 m depth, two current meters were mounted at 3.5 m and 7.5 m from the surface. At 20 m depth, the current meters were mounted at 5 m and 10 m from the surface.

Drifting buoy survey

Measurements of current dispersal characteristics were undertaken using GPS units and drifting buoys (drogues). These measurements were necessary for the validation of the predictive model.

Drifting buoys were manufactured in a local workshop in Dagupan and then deployed in Bolinao, Dagupan and Taal Lake.

Drifters of various designs to measure physical oceanographic features have been used from oceanic to inshore areas (Burrows et al., 1999; Yanagi et al., 1982). Inshore drifter surveys have been commonly undertaken around long sea outfalls, with surveys around fish farms less common. In this context,although the principles of dispersion measurement are well tested application of this technology around fish farms is novel. Concurrent meteorological measurements of wind speed and direction is desirable.

The system used was with drifting buoys with numbered flags which were tracked at 10 to 30 minute intervals using hand held logging GPS unit by approaching the drifter in a small vessel and fixing position with the hand held unit. This approach limits the accuracy and timing of the positional data. If drifters were grounded or became snagged on moorings or debris then the drifters were recovered and removed from the trial.

Water column sampling with the CTDO-probe

Information about conductivity, temperature, salinity, and oxygen in the water column is important for understanding the condition and the dynamics of an area. In addition, these parameters are essential for the modeling work. These hydrographic data were measured with an electronic CTDO-probe (Sensordata). The probe has sensors for measuring conductivity (salinity), temperature, depth, chlorophyll, turbidity, and oxygen. During sampling the probe was lowered to the bottom and slowly pulled back to the surface. The probe was programmed to take measurements every five seconds.

Secchi-depth and water quality sampling

The Secchi-depth was measured with a standard Secchi-disk (diameter 25 cm).The use of a Secchi-disk is a very well known method for measuring the water transparency and the color of the water. These data give information about the amount of particles in the water. The particles are either related to production in the water column (phytoplankton) or particles which come from the drainage area or sediments (sand, dust). The Secchi-depth was measured at all benthic and CTDO stations.

Water samples were taken with a Niskin water sampler or a Rutner water sampler at 2 m depth. In Bolinao, the stations sampled were the same stations monitored by the University of the Philippines Marine Science Institute (UPMSI) for their long trend studies. In Dagupan, the stations of the BFAR-NIFTD were visited in their monitoring programme. In Taal Lake, water samples were taken from some new stations in addition to the stations that the

BFAR Ambulong Station are monitoring. The samples were analyzed by the UPMSI for the following parameters: NH_3, NO_2, NO_3, PO_4 and chlorophyll-a. In Dagupan, water samples were analyzed by NIFTDC and in Taal Lake by the BFAR Ambulong Station.

Sediment sampling (Benthic stations)

Sediments are often used as indicators for evaluating the environmental status of an area. It takes much longer time to change the condition of the sediments compared to the water quality parameters. Water quality parameters give a snap shot of the conditions while sediments tell you how the conditions have developed over a longer time period. Therefore sediment samples are very good indicators of the environmental condition.

The distribution and abundance of organisms, numbers of species and community structure were analyzed as a pilot faunal registration. These parameters give good indications of the environmental state of the area.

Sampling was carried out with a 0.05 m2 modified Van Veen grab. The grab had hinged and lockable inspection flaps constructed of 0.5 mm mesh. The upper side of each flap was covered by additional rubber flap allowing water to pass freely through the grab during lowering, yet closes the grab to prevent the sediment surface from being disturbed during hauling.

At each station one chemical and one biological grab sample were taken. Sub-samples for analyses of grain size, total organic carbon (TOC) and total nitrogen (TN) were taken from the upper 2 cm layer of the chemical samples. Each sample was visually inspected to ensure there was no sediment disturbance. The samples were frozen at -20°C.

The volume of the sediment that contained the biological samples was recorded and gently sieved through a 1-mm round hole sieve immersed in sea water. The fauna for the semi-quantitative sample were then preserved with 4% formaldehyde solution that was stained with rose bengal and neutralized with borax.

Each sediment sample was described with respect to sediment type, smell, color, larger living animals, and other obvious features (i.e., visible organic layer, bacteria, feces, fish food, etc.).

In areas with bad environmental conditions, the sediments had high organic content (Fig. 2) and smelled sulfidic. In these samples, there were no live animals recorded. Stations with bad sediment conditions were often related to areas with high fish farming activity. In areas with less fish farming there were less or no sulfide smell, were low in organic content, and live animals were recorded.

Figures 3, 4 and 5 show the Bolinao, Dagupan and Taal Lake sampling sites, respectively. Table 1 summarizes the number of surveys and sampling stations in each site.

Figure 2. Sediment samples from sites with different environmental conditions. The left picture is of sediments close to a fish cage; the sediments have high organic content, no live animals and H2S odor. Right picture is from an area far away from a fish cage where the sediment is in relatively good condition.

Item	Bolinao	Dagupan	Taal
No. Surveys	3	1	2
Number of Stations			
Current Meter	16	7	11
CTDO	102	42	117*
Secchi depth	86	41	42
Grab Sample	63	8	25
Water Sample	32		

Table 1. Survey areas and sample sites. (*Only 57 stations are shown in the map.)

PRODUCTION SURVEY

A survey of aquaculture production in each of the survey areas was undertaken in order to link aquaculture production to the environmental impacts observed.

The following information was collected from a number of farms in each area:

- Species cultured
- Growth rate
- Biomass
- Stocking density
- Survival
- Health problems and status

Fish farm registration

Fish farms were counted, noted if operational or nonoperational and registered with GPS reading (where possible). This method was used for Bolinao and Dagupan.

In Taal Lake the cages were too numerous to count individually by boat so a number of alternative methods for estimating the number of cages were used and their accuracy compared to an aerial survey.

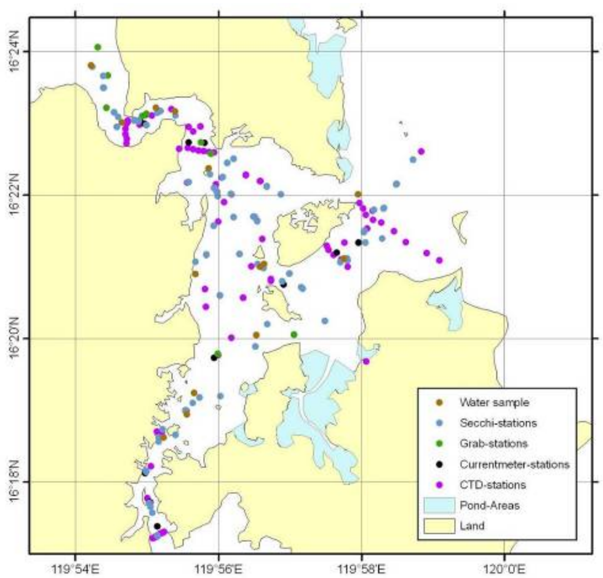

Figure 3. Sampling sites in Bolinao; April & October 2005 and February 2006.

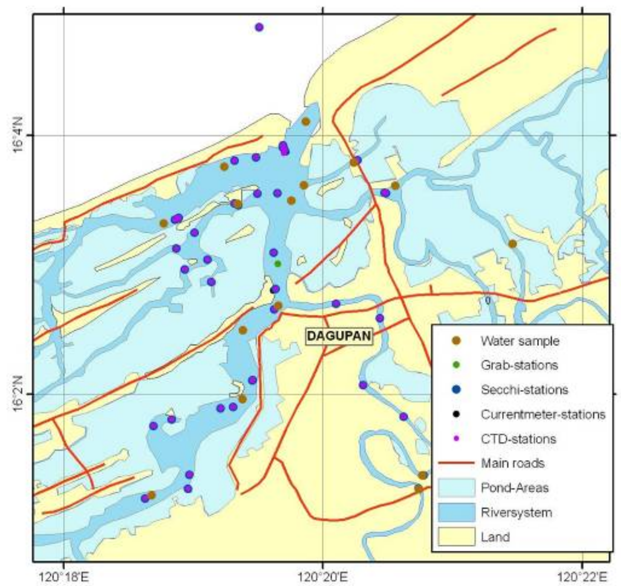

Figure 4. Sampling sites in the Dagupan estuary: April 2006.

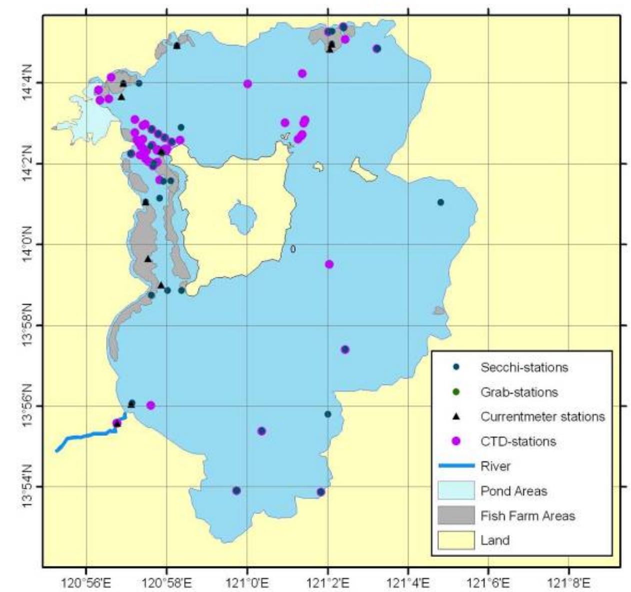

Figure 5. Sampling sites in Taal Lake: October 2005 & April 2006.

Estimates of the surface area of cage zones were made using satellite imagery. Images were downloaded from Google earth. From the raw images it was not possible to identify areas with cages but with adjustment of the brightness and contrast, the areas with cages were able to be identified (Fig. 6). The enhanced image from satellites allowed accurate measurement of surface area but the date of the image used by Google earth is not known. A sub-sample of the number of cages per hectare was measured with a boat in different areas. Density of cages varied between 5 to 25 cages per hectare with an average of 15 per hectare. As the date of the image was not known, this method was discarded.

Figure 6. Top: Image of a cage area in Taal Lake. Bottom: Enhanced image of cage area. Image courtesy of Google Earth.

Another method used to try and estimate the surface area of the cage zones was to follow the perimeter of the cage area with a small boat recording the boat track using a GPS. This method was accurate for the measurement of surface area of cage zones but took a lot of time.

Another method that was evaluated was the taking of a panorama of digital photographs from a vantage point and counting cages from the photographs (Fig. 7). Using this method, it was estimated that there were 1,037 cages in the Sampaloc area (1,371 counted from the aerial survey). It was difficult to count the cages in the distance accurately. In addition there were very few vantage points high enough to get a full view of the cages on the lake. This method was also discarded.

An aerial survey was undertaken by flying over all the production areas at 100 m height and taking digital photographs (Fig. 8). This allowed photographs of all the cages to be taken and analyzed (see Figs. 8 and 9). It was found that the most accurate method to estimate a large number of cages was by aerial photography.

SUMMARY

Environmental and production surveys were made and measurement methodologies were tested in three sampling locations in the Philippines: Bolinao, Pangasinan (seawater site), Dagupan estuary (brackishwater site), and Taal Lake (freshwater site) for the purpose of determining the impact of aquaculture in these sites. For the environmental survey, measurements were made for bathymetry, current and current dispersal characteristics, conductivity, temperature, salinity and oxygen, water transparency and quality, and sediment content. For the production survey, information on species cultured, growth rate, biomass, stocking density, survival rates, and health status were gathered from aquaculture areas in the three sites. Aerial photography provided the most accurate method to estimate the number of fish cages in a site.

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Figure 7. Panorama photography of fish cages in Taal Lake.

Figure 8. Composite of aerial photographs of an area in Leviste, Taal Lake.

Figure 9. Enhanced and zoomed aerial photograph of cages in boxed region in Figure 8.