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Final report – Bolinao

Environmental Monitoring and Modelling of Aquaculture in risk areas of the Philippines (EMMA)

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1 Introduction

Lingayen Gulf, and the Bolinao-Anda reefs on the northwest section of the gulf, is among the most data- rich estuarine systems in the Philippines. The major reason for this is its importance as a major fishing ground and aquaculture production area in the northern area of the country, and the presence of the Bolinao Marine Laboratory of the University of the Philippines Marine Science Institute next to the reef system.

Bolinao is a municipality in the province of Pangasinan on the northwest coast of Luzon, Philippines (McManus et al. 1990). One of 18 towns bordering the Lingayen Gulf, Bolinao has one of the most extensively developed reef systems and associated habitats in northern Luzon (McManus et al. 1992). Demersal fish, shellfish, and seaweeds living in reef and seagrass areas dominate the fisheries of the town. In 1993, the Lingayen Gulf was declared an environmentally critical area under Proclamation 156. The Bolinao- Anda reefs are the only coralline section of the gulf and are the spawning and feeding grounds for a significant number of fish and invertebrate species.

From an environmental perspective, significant indicators of unsustainable levels of resource extraction were evident in the late 1980s. Talaue-McManus and Kesner (1995) documented the collapse of the valuable sea-urchin fishery in 1992. The once-booming sea urchin industry was shut down indefinitely after the urchins had been exploited nearly to extinction to satisfy export demand for roe. This was in despite the existence of town resolutions limiting the fishing season and establishing a minimum harvestable size. Data gathered over a 4-year period (1988–91) revealed evidence of overharvesting of reef fish: a decrease in adult-fish density and species diversity, as well as in the size of reproductively mature fish (McManus et al. 1992). A survey of the coral reefs of the Lingayen Gulf conducted during 1987 and 1988 showed that sites in the Bolinao–Anda system had 30–51% live coral cover; siltation and the use of dynamite and poison posed the major threats to the reef (Meñez et al. 1991).

1.1 Reef system

A 1986 study by the Marine Science Institute at the University of the Philippines, documented significant damage to Bolinao’s coral reef system. Researchers found that about 60 percent of the region’s corals had been killed, mostly through destructive fishing practices that relied on dynamite and cyanide to enhance catches (McManus et al. 1992). Fishermen, fish vendors, and shell craftspeople had noted diminished catches, changes in dominant species, and decreases in the size of mature fish.

1.2 Sea grasses

Seagrass form extensive cover, especially, along the coastline. These habitats are among the most productive in the world, comparable to tropical rainforest (Birkeland, 1985). Seagrass and primary productivity influence other organisms, such as fish and invertebrates, that use them either for food, shelter, or both (Howard et al., 1989). Their importance to tropical fisheries has been previously documented (Estacion and Alcala, 1987; Fortes, 1989). It has been argued that seagrass communities influence the production of nearby habitats such as coral reefs and mangrove forest (Birkeland, 1985).

1.3 Fishing

About one-third of Bolinao’s 30 villages and 50,000 people depend on fishing to make a living (McManus et al. 1992), and the Bolinao-Anda coral reef complex serves as the spawning ground for 90 percent of Bolinao’s fish catch. More than 350 species of vertebrates, invertebrates, and plants are harvested from the reef and appear in Bolinao's markets each year (Maragos et al. 1996).

To regulate and rationalize aquaculture operation, the Lingayen Gulf Coastal Area Management Plan (LGCAMP) was formulated in the early 90s. In addition, the Local Government Unit (LGU) of Bolinao formulated the ten-year Coastal Development Plan (CDP) that contained the technical considerations for sustainable management of fish pens and designate areas for fish pens and fish cages operations. As an implementing guideline of the CDP, the Municipal Fishery Ordinance (MFO) was passed.

1.4 Aquaculture

Despite the regulation, fish pens and fish cages were constructed and operated both legally and illegally, with milkfish (*Chanos chano*s) as the main cultured species. A fish pen is built in shallow waters and is made up of bamboo poles surrounded by a fish net. A fish cage is in deep waters and uses either fiberglass or steel and nets held up by floaters.

In most of the periods, the numbers of permits issued were way below the actual survey or inspection, an indication of the existence of illegally constructed structures. Moreover, the number of structures constructed exceeded the 544-unit carrying capacity of the Caquiputan Channel, the main aquaculture site.

Table 1. Number of aquaculture structures in Bolinao, 1995-2000. (Source: McManus and Thia-Eng (eds.), 1990)

Date of survey	Number of cages/pens	Source
Jan 2002e	621	(permits officially issued); 1067(LGCAMP count)
2001d	1170	(AFMA-DMEQCMA study)
2000	371c	(permits officially issued); 993 (MFRMP survey)b
1999b	797	(ocular survey)
1998b	476	(permits officially issued)
1997a	703	(permits officially issued); 1076 (ocular survey)
1995	242	(start of permit issuance)

a Verceles, Mcmanus and Aliño, 2000,
b MFRMP (on going study) and personal communication with Dr. M.L. SD. McGlone of UP-MSI,
c CRM Office, Bolinao,
d AFMA-DMEQCMA (on-going study)
e PDI, February 9, 2002

Overstocking and excessive feeding practices were claimed to cause deterioration in water quality that affects both the aquaculture industry and the non-cultured species. No study has been done to assess the value of damage due to deterioration in water quality caused by aquaculture operation.

Bolinao is considered to have the most extensive monitored mariculture activities in Lingayen Gulf. From 1995, the trends in the number of fish pens and cages have shown a steady increase then decline in 1999, followed by an increase in 2000. The decline was mainly due to low fish growth associated with the deterioration in the quality because of poor mariculture practices. Bolinao has the highest number of fishpens/cages of about 1170 units (32 units sq/. km).

Figure 1. Cage culture in the Bolinao Bay area (Northwest channel).

Fishpen operators have needed to extend their culture period from 5 to 6 months in order to produce fishes of marketable size (500 g). In previous years, 3 months were sufficient to produce marketable size. Harvest frequency has been reduced from three or two cycles per year. The major reason for the deteriorating water quality is caused by low water exchange in the Bay resulting from high numbers of cage/pens which cause drag on tidal flushing, stocking density, and excessive feeding.

In February 2002, the worst fish kills in the history of the Philippines hit the aquaculture sites in Bolinao causing huge damage valued at Php P 600 million. It was this fish kill that triggered the formulation of this project.

1.5 Environmental monitoring and modelling

Environmental monitoring and modelling is often for being able to carry out sustainable aquaculture in an area. The data (information) needed for environmental monitoring is different physical, chemical and biological parameters. In most cases there is a need for going out in the field to collect new data. However historical data are also really useful information both for the modelling but also the environmental monitoring. When historical data and new data are collected these data will be used for doing the modelling work. It is important to remember that the better the background data are the better and more precise will de output of the modelling be.

The most important parameters for environmental monitoring and modelling are:

- Bathymetry (depth recordings) of the area
- Tidal range and current speed, direction and dispersion
- Physical parameters - Temperature, turbidity, salinity, oxygen, profile through the water column
- Water quality – chlorophyll, phosphorous, nitrite, ammonia
- Sediment analysis (biological and chemical)
- Weather data - wind direction, speed, temperature

2 Summary of survey results

2.1 Study area

Bolinao is considered to have the most extensive monitored mariculture activities in Lingayen Gulf. The investigations in this study have focused on the area (Bolinao Bay) between the northeast mainland of Cape Bolinao, Santiago Island and Cabarruyan Island. The bay has three inlets / outlets. The two up in the northern part of the bay are connected strait out to open water. However, the southern entrance is connected to Tambac Bay which also has a lot of aquaculture activity. The Tambac Bay was also affected by fish kill episodes. The studied bay are relatively shallow and the average depth in most of the area are less than 6 meters deep. The study area is shown in Figure 2.

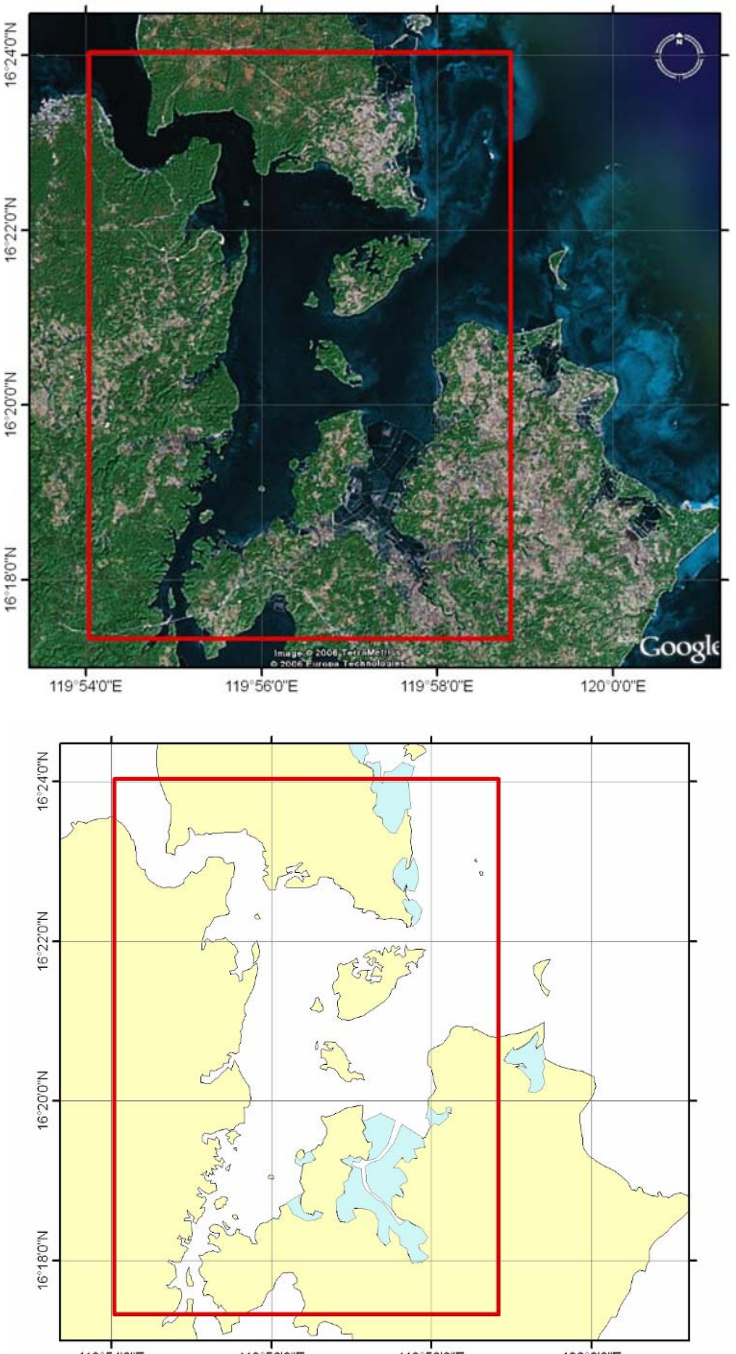


Figure 2. Satellite image of the Bolinao Bay (upper figure from Google earth). Below - a digitalised map of the area. Area included in this study is within the red square.

2.2 Bathymetry

Detailed knowledge about the bathymetry in an area is vital information for being able to model the water exchange in an area. There exist sea maps with depth recording for the Bolinao Bay but the resolution (number of recordings) was not good enough for the modelling. There are especially in the entrances of the Bolinao Bay that more information about depth was needed (Figure 3). 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 area. This setup measure depth with an echosounder and a GPS store the tracks automatically tagged with the date and time of creation, as well as water temperature and depth. This setup is part of the equipment that is donated to BFAR for use in future projects. All the collected data were used for the modelling. In Figure 3 transects of the new depth recordings are illustrated. The data collected can be put straight into the model or be used for making new bathymetry maps for the area. A detailed map of the northwest entrance is shown in Figure 4.

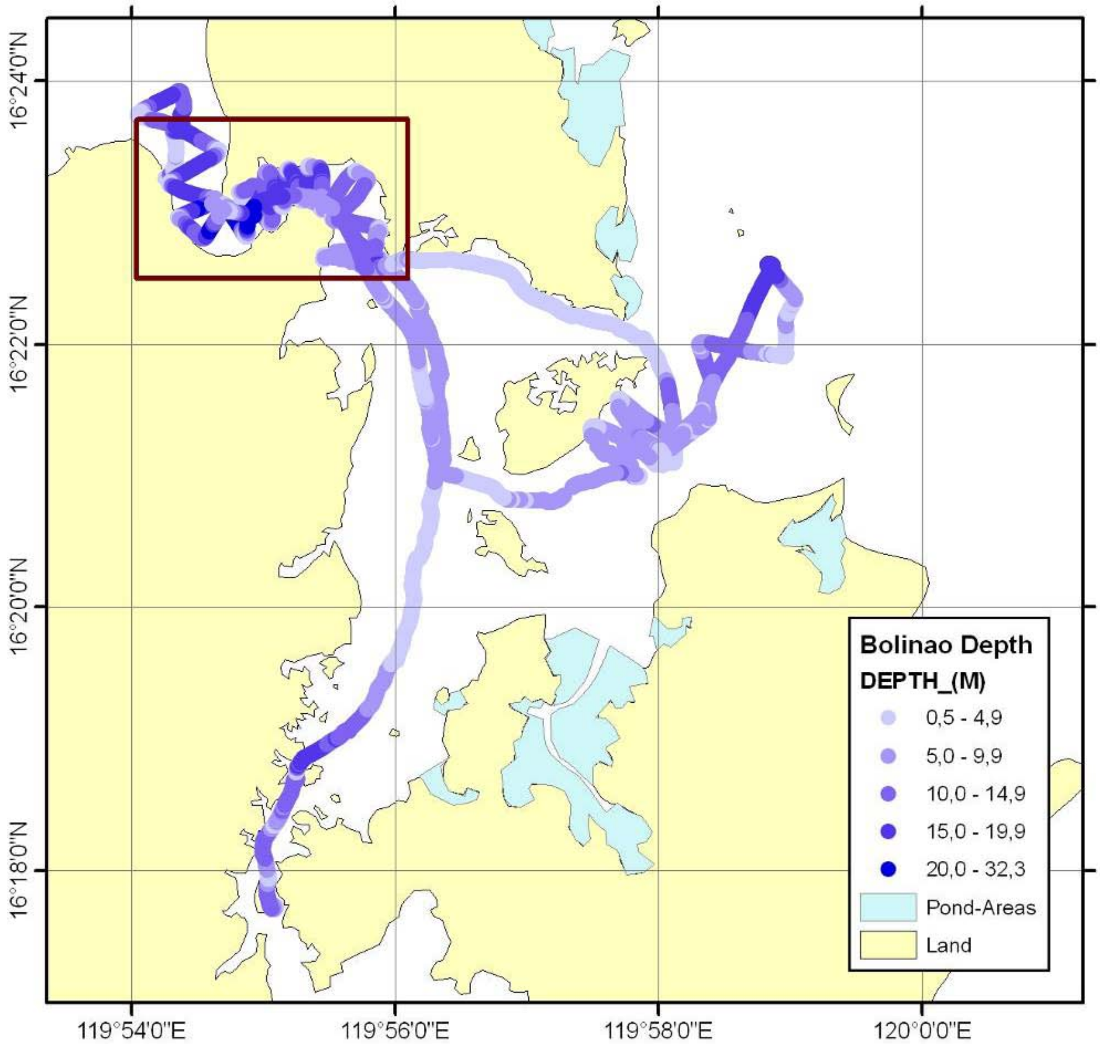


Figure 3. Map of Bolinao Bay demonstrating the new depth recordings. Light blue illustrates deep areas while light blue illustrates shallower areas. The rectangular indicates the area for the detail illustration in Figure 4.

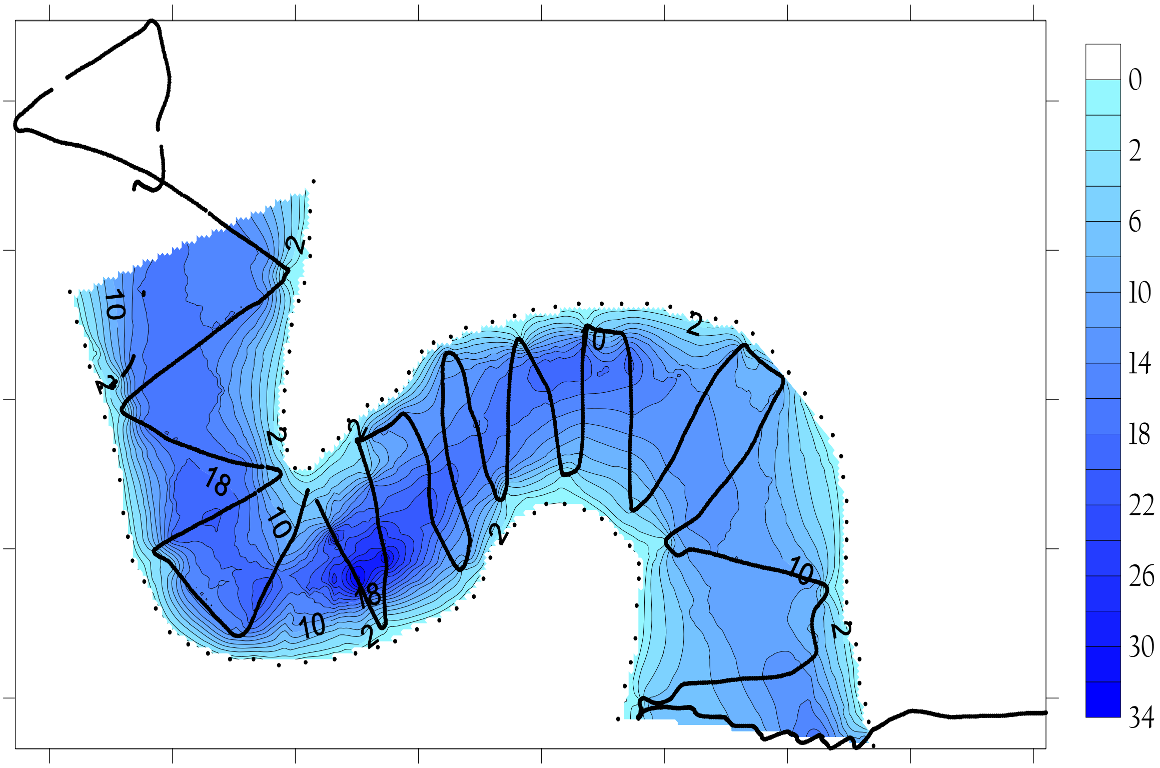


Figure 4. Detailed Bathymetry map of the northwest channel (entrance) of Bolinao Bay. Light blue illustrates deep areas while light blue illustrates shallower areas.

2.3 Current meters

Information about the currents (speed, direction, volume) in an area is vital for doing the modelling. This information is used for modelling water exchange which again 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 meter model SD-6000 was used in the first survey. This is a compact vector averaging current meter with memory capacity for up to 6000 combined data sets of current speed, direction and temperature. For the second and third fieldtrip the new current meters, RCM 9 LW from Aanderaa in Norway, was used (Figure 6).

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 calculation of the current speed and direction. The scattering particles are normally plankton, gas bubbles, organisms and particles stemming from man-made activity.

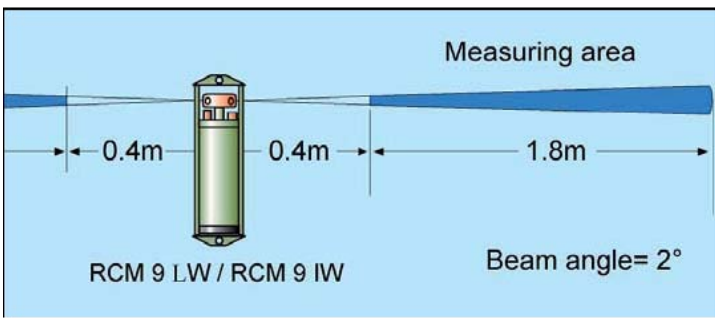


Figure 5. Illustration of the measuring area for the RCM 9 LW current meter.

Two of these current meters are set up 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 10 – 34 days per station to get a really good picture of the current in an area. However due to time limitation most of the current meters were approximately 24 hours at each station. The area is quite shallow so only one current meter were used at each station. For most of the stations the current meters were placed in the middle of the water column.

A typical mooring (set up) for the current meter rig is illustrated in Figure 7. The set up is dependent on the depth on the station. When the depth is less than 10 meters usually only one current meter is mounted in the rig (6 meter depth). For areas with 15 meter depth usually two current meters are mounted at respectively 3.5 meter and 7.5 meter from the surface. At 20 meter depth the current meters are mounted at respectively 5 meters and 10 meters from the surface.

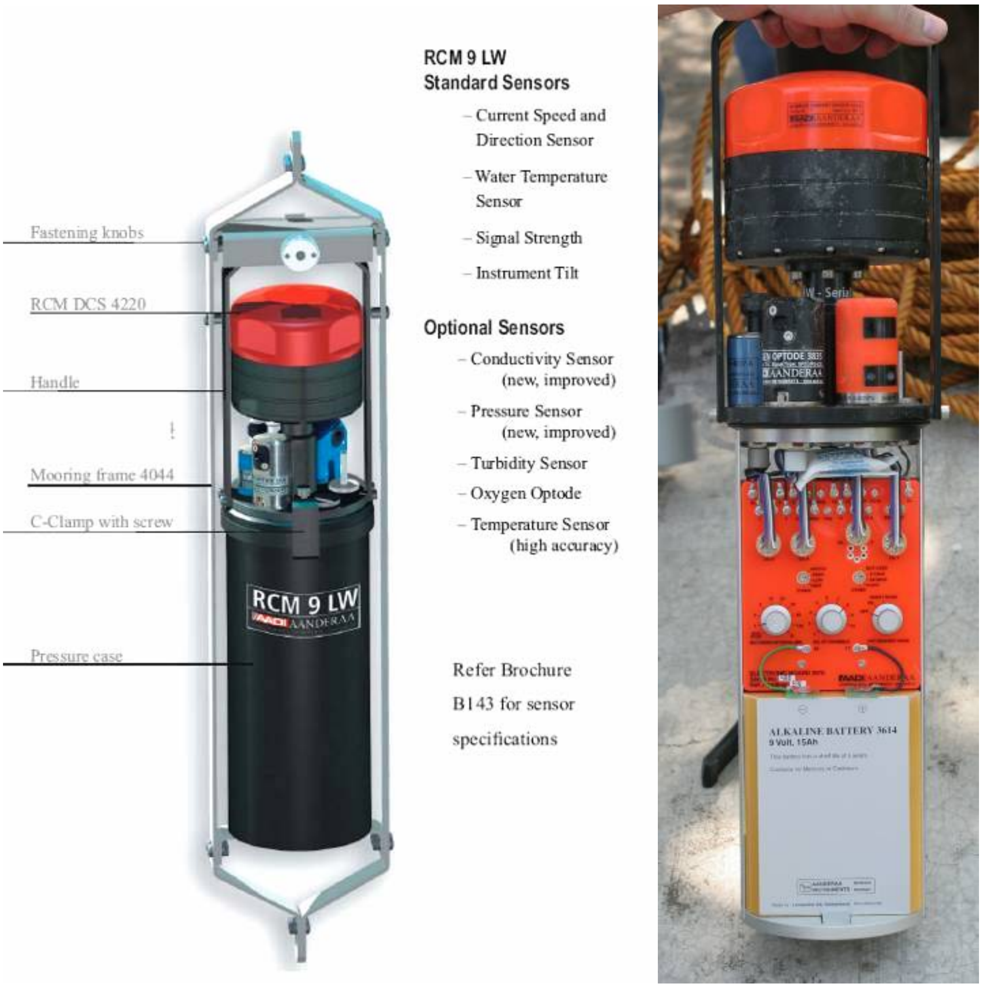


Figure 6. Aanderaa RCM 9 LW current meters equipped with sensors for measuring conductivity, turbidity, oxygen and pressure (depth).

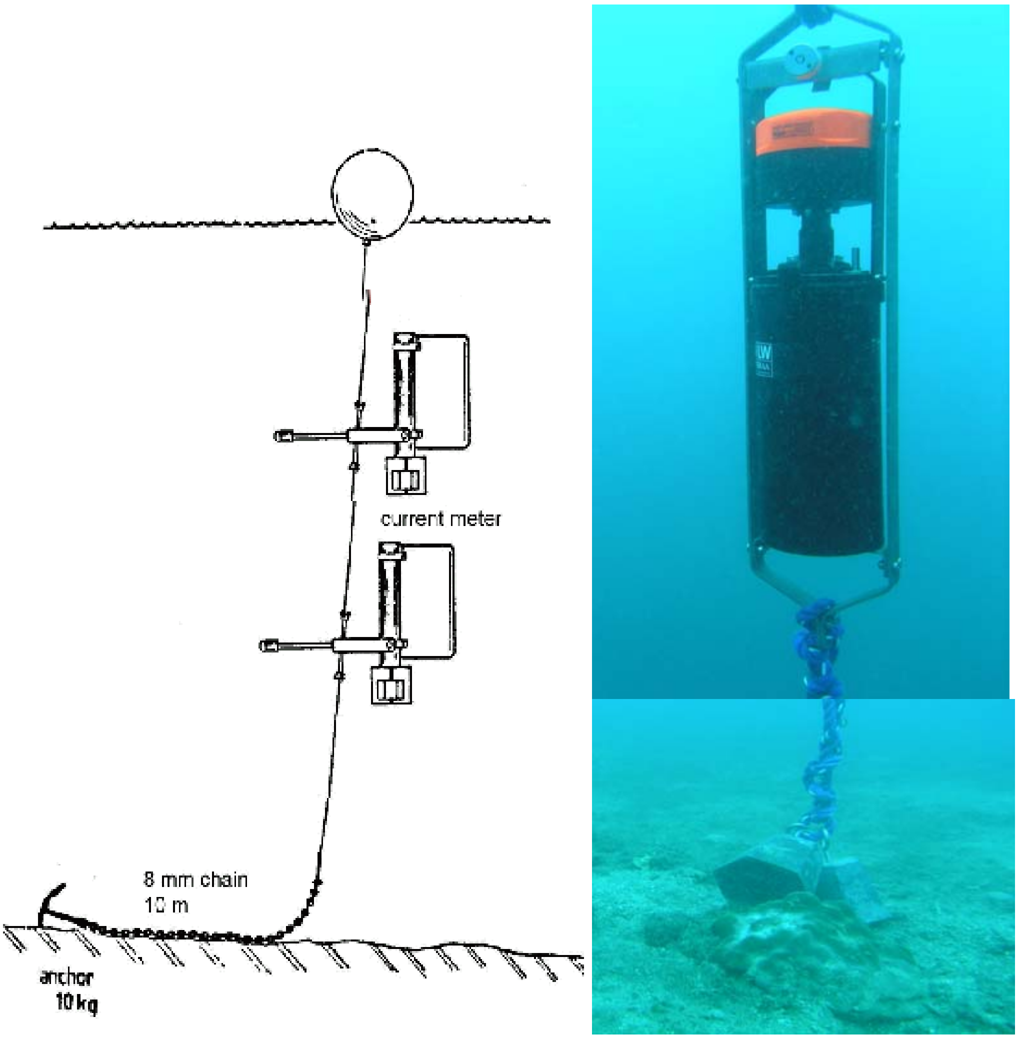


Figure 7. A typical set up (mooring) for current meter rig (Left). Right; picture of a current meter in a rig connected to the leaden weight.

In the Bolinao Bay 15 stations with one or two current meters where taken during the 3 different field trips (Figure 8). In most of the station the depth is less than 10 meters and therefore only one current meter were mounted. However at the station in the northwest entrance where the depth is more than 15 meters and therefore two current meters where used in the rig.

The current measurement data from the three main entrances (CM 37 in the northwest, station CM01 in the northeast and CM06 in the south) reveals the main current patterns for the Bolinao Bay. Further when all the data from the current measurements are put into the model a clear picture of the water exchange for the whole Bolinao Bay is clarified (see chapter “Modelling of carrying capacity”). The current measurements from the 3 entrances are illustrated in Figure 9, Figure 10 and Figure 11.

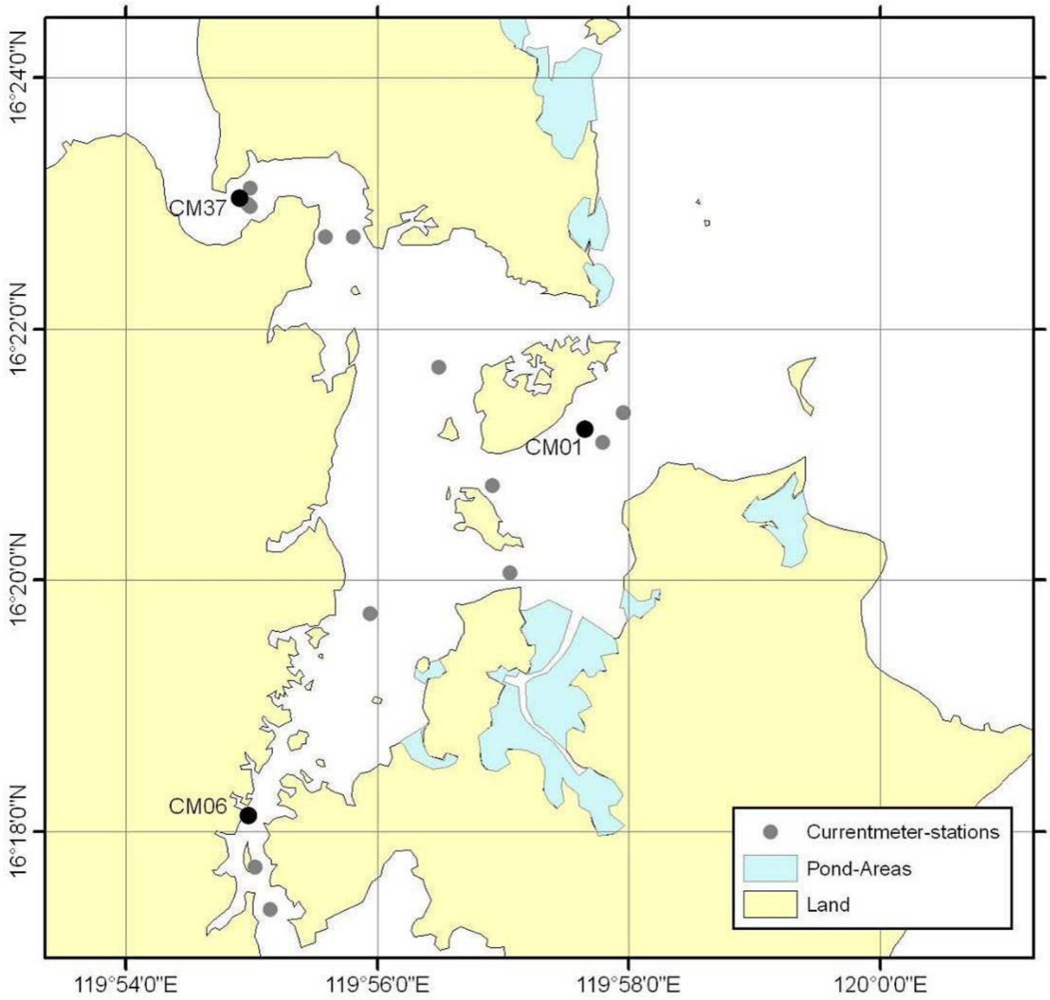


Figure 8. Map illustrating the 15 different current meter stations that was used during the 3 cruises in 2005. Station CM37, CM01 and CM06 is indicated with numbers.

The current measurements from the narrow channel in the northwest of the Bolinao Bay indicate that the amount of water transported out of the channel is higher compared to the transport into the channel (Figure 9, middle part). The current are moving out of the channel for longer time periods compared into the channel (Figure 9, middle figure). However there are no systematic differences between the speed of the current in and out of the channel (Figure 9, lower figure).

The current measurements from the wide entrance in the northeast indicate a tidal cycle of water moving in and out. The speed current is up to 20 cm/sec (Figure 10). The current measurements from the narrow channel in the southern part of Bolinao Bay reveal a almost straight south north movement of the water. The recorded current speed is up to 40 cm/sec and the amount of water per m^2 is up to 150 litres per sec. These levels are really high compared to the other entrances.

Based on the data collected with the current meters and calculations with the modelling the main water exchange take place through the northeast and the southern entrances. The Northwest entrance function more like a compensation valve for the water masses in Bolinao Bay.

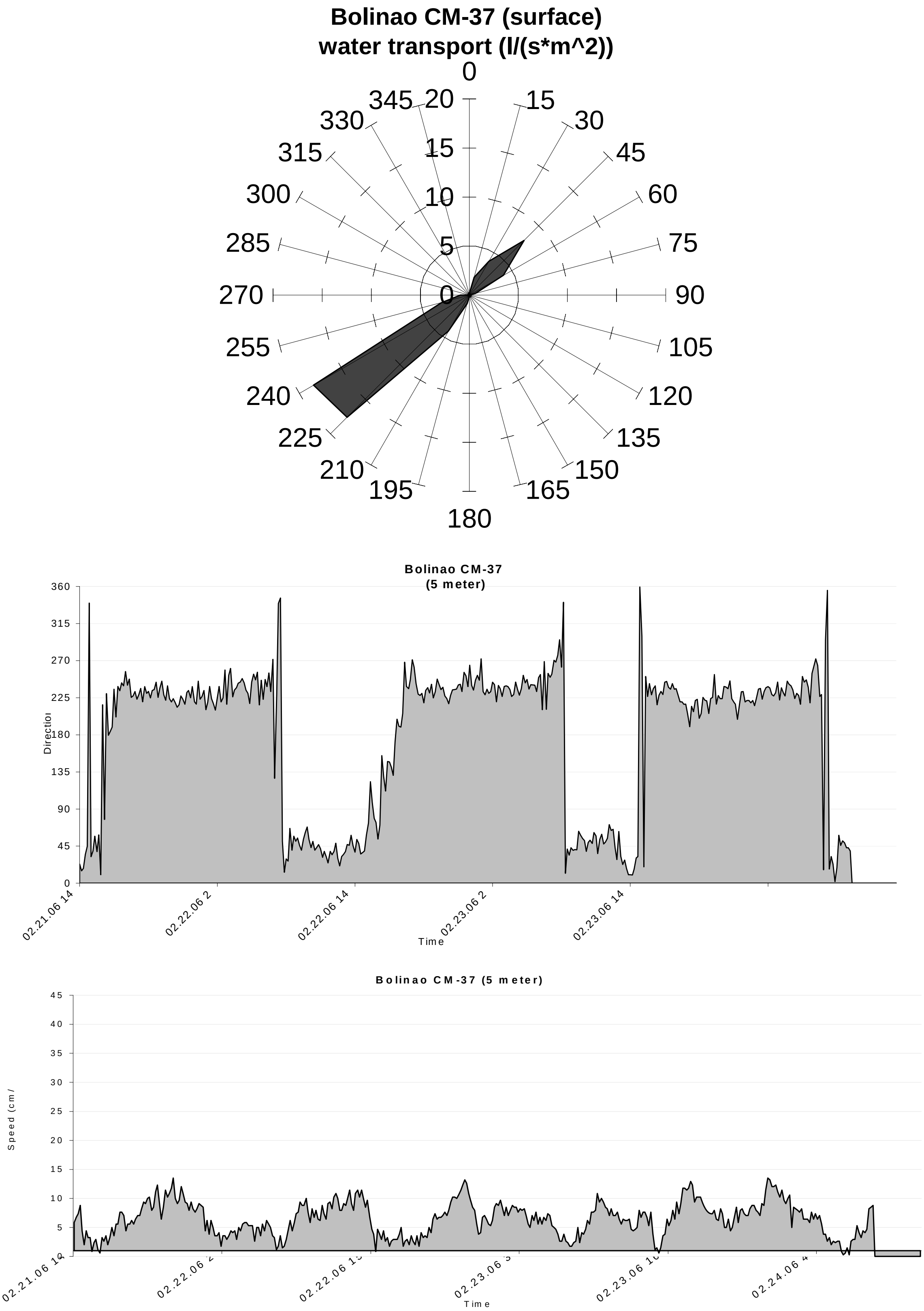


Figure 9. Current measurements from station CM37 (northwest entrance) of the Bolinao Bay. Upper: Current-“rose” illustrating current direction (0-360 degrees) and water transport (l/sec per m^2). Middle: illustrates the current direction (0-360 degrees). Lower: Illustrates the current speed (cm per sec).

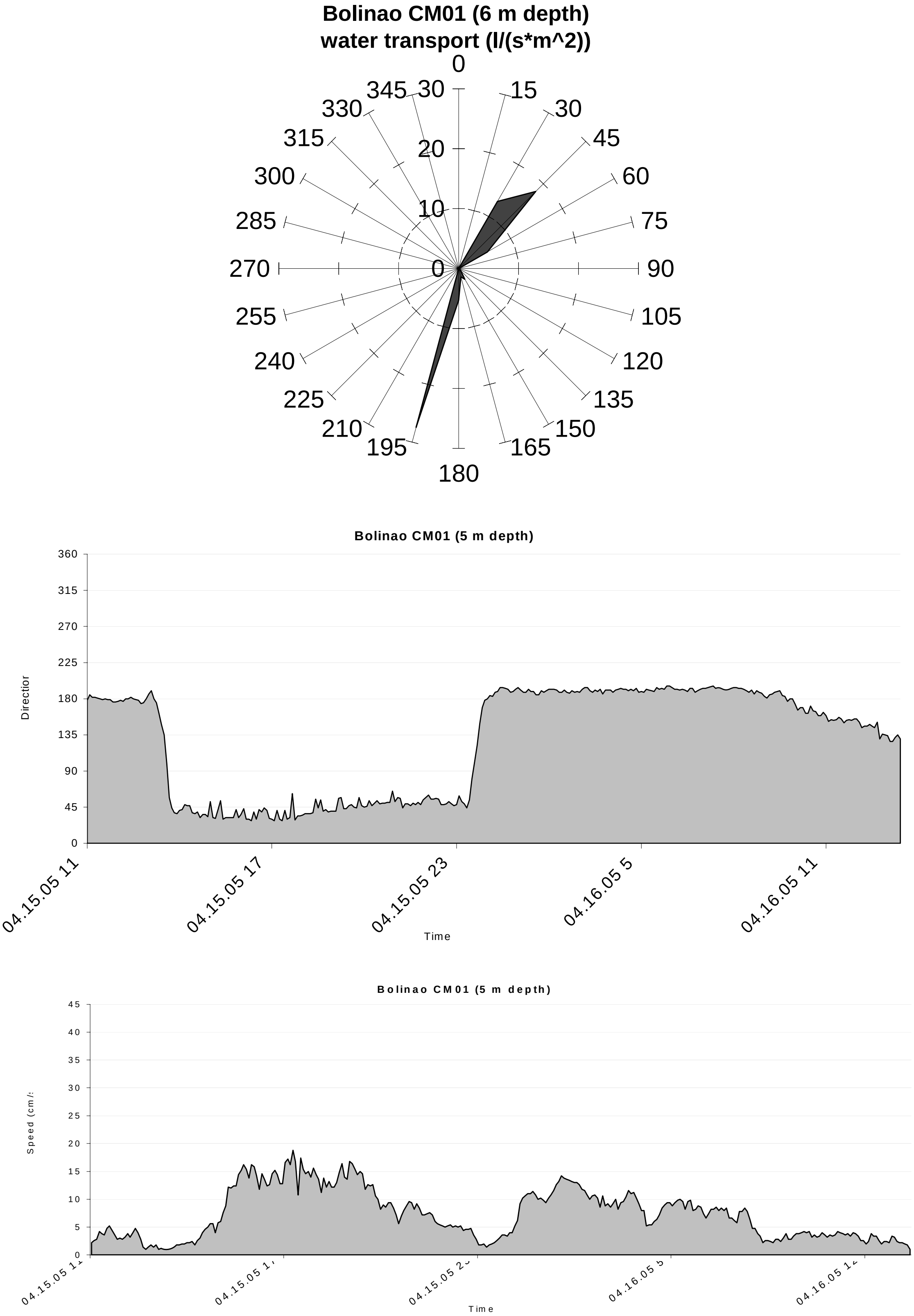
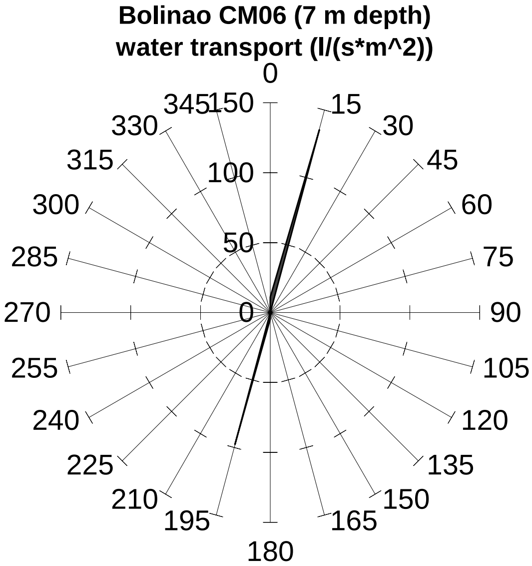
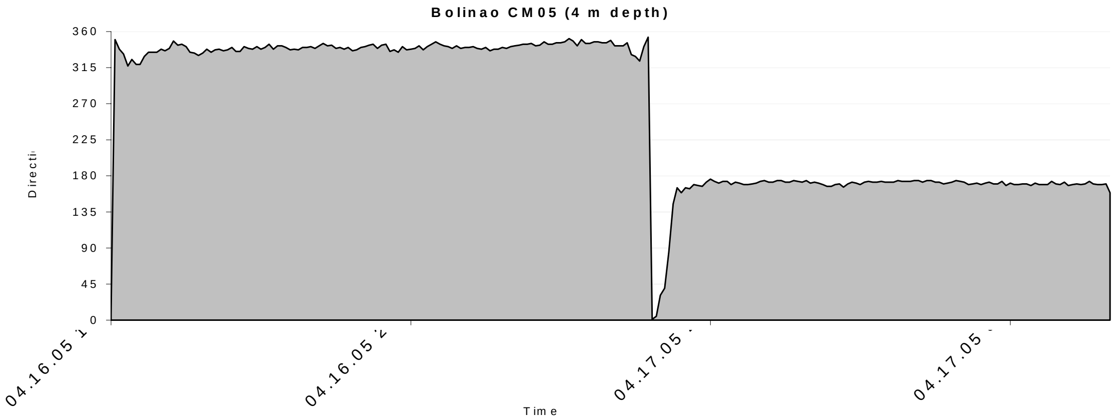


Figure 10. Current measurements from station CM01 (northeast entrance) of the Bolinao Bay. Upper: Current-"rose" illustrating current direction (0-360 degrees) and water transport (l/sec per m^2). Middle: illustrates the current direction (0-360 degrees). Lower: Illustrates the current speed (cm per sec).





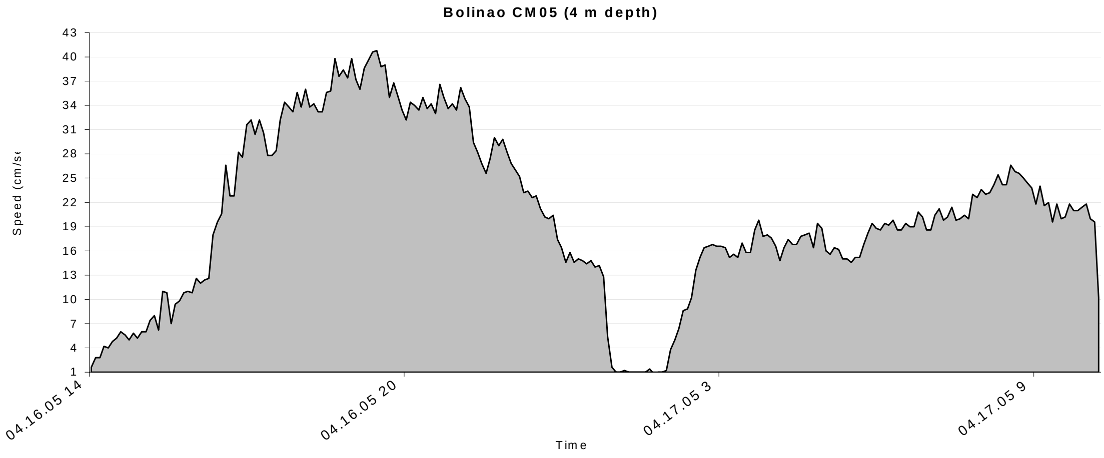


Figure 11. Current measurements from station CM06 (southern entrance) of the Bolinao Bay. Upper: Current-"rose" illustrating current direction (0-360 degrees) and water transport (l/sec per m^2). Middle: illustrates the current direction (0-360 degrees). Lower: Illustrates the current speed (cm per sec).

2.3.1 Water quality parameters

The Secchi-depth was measured with a standard Secchi-disk (diameter 25 cm). Water samples were taken with a Niskin water sampler at 2 meters depth. All the stations are similar to the station that the University of Manila is using in their long trend studies. Two sampling trips were carried out during the project (April 2005 and February 2006). The samples were analysed at the University of Manila for the following parameters NH_4, NO_2, NO_3, PO_4 and Chlorophyll-a.

Turbidity sampling (Secchi-depth)

The use of a Secchi-disk is a very well known method for measuring the water-transparency and the colour of the water (Figure 12). These data gives 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.

The Secchi-depth varied from less than one meter to more than 7 meters (Figure 12). The Secchi-depth was generally lower in the area close to the southern entrance. The reason for this, even though the area has a good water exchange is that the water coming in through the southern channel has its origin from Tambac Bay were the Secchi-depth also is low. The Secchi-depth in the outer part of the northwest and northeast entrance is markedly better due to water with little particles coming in from the open sea.

Figure 12. Secchi-disk readings in Bolinao Bay 2005.

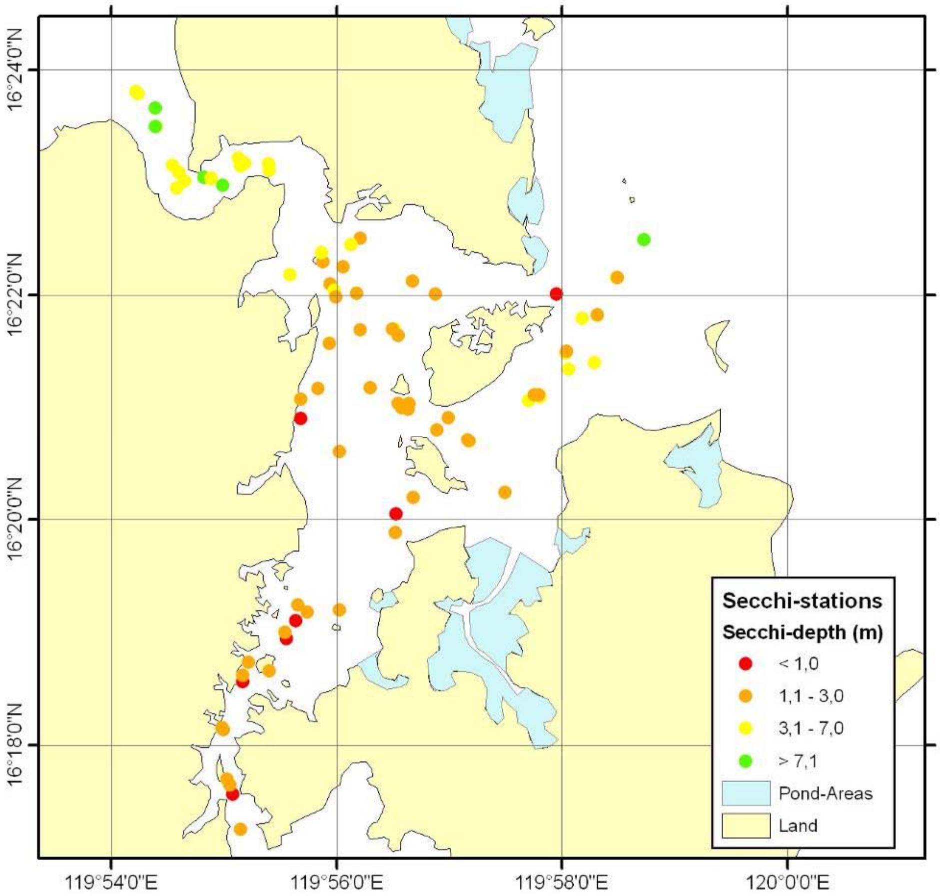


Figure 13. Secchi-disk measurements from the Bolinao Bay April 2005 and February 2006. The colour of the dot indicates the Secchi-depth (see legend in Figure).

Figure 14. Niskin water sampler was used for collecting the water samples.

Two of the most important water quality parameters related to aquaculture and fish kills are the chlorophyll-a and phosphate levels in the water. Chlorophyll is a green photosynthetic pigment found in most plants, algae, and cyanobacteria and measured in water it tells us something about the production in an area. Production is again closely related to available nutrients in the water.

In Bolinao Bay the measured levels of Chlorophyll-a varied from 0.56µg/L up to 29.62µg/L (Figure 15). The average value for the samples was around 3.0µg/L. These values are in the same range as previous numbers from this area. However the chlorophyll-a are related to the production (amount of phytoplankton) in the water column and the levels will therefore change during day and night and there will also be seasonal differences. It seems to be generally higher levels in and close to the southern entrance. However in February 2006 the levels were also high at some of the station in the northern channel.

The phosphate levels varied from 0.1µM (9.5µg/l) to 1.35µM (128.2µg/l). The average value was 0.59µM (56.3µg/l). The highest levels were registered in the southern part of the area. The lowest levels were registered in the Northwest channel close to the intensive fish farming areas.

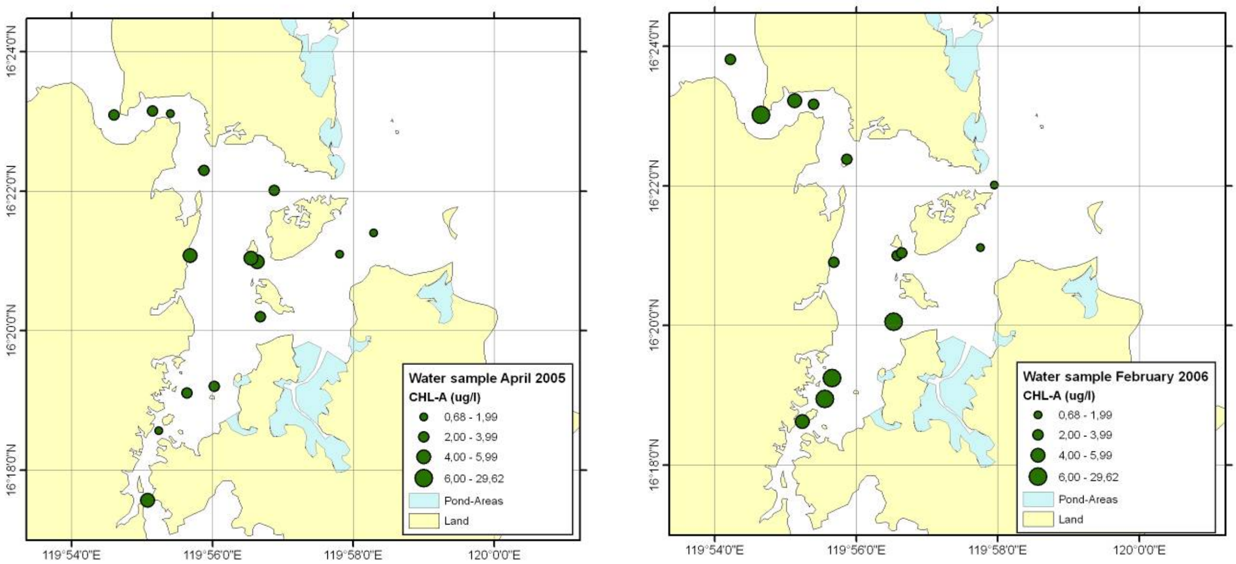


Figure 15. Chlorophyll-a measurements in the Bolinao Bay April 2005 and February 2006. Green dot indicates sampling stations and the size of the dots indicates levels (see legend in figure).

2.3.2 Water column sampling with the CTDO-probe

Information about conductivity, temperature, salinity and oxygen in the water column is important parameters for understanding the condition and the dynamic of an area. In addition these parameters are sensual for the modelling work. These hydrographic data was measured with an electronic CTDO-probe (Sensordata). The probe that was donated to BFAR has sensor for measuring conductivity (salinity), temperature, depth, chlorophyll, turbidity and oxygen. These are all important parameters for evaluating the conditions of the water column.

During sampling the probe was lowered slowly to the bottom and slowly pulled back to the surface. The probe was programmed to take measurements every 5 seconds. The measured parameters will have seasonal and day – night changes. All the CTDO readings (approximately 100) are plotted in Figure 17.

Figure 16. Sampling with the CTDO-probe.

The oxygen levels in the bottom water of Bolinao Bay measured in February 2006 varied between 0.57 mg/l and 5.3 mg/l. Generally the lowest levels were found in the southern part of the Bolinao Bay (Figure 18). Low levels of oxygen in the water indicate little water exchange with little new oxygenated water coming in to an area. Further areas with little oxygen are in this case also related to the areas with high aquaculture activity. Release of nutrient (feed spill and fish feces) to the water increase the production of phytoplankton which again increases the demand for oxygen.

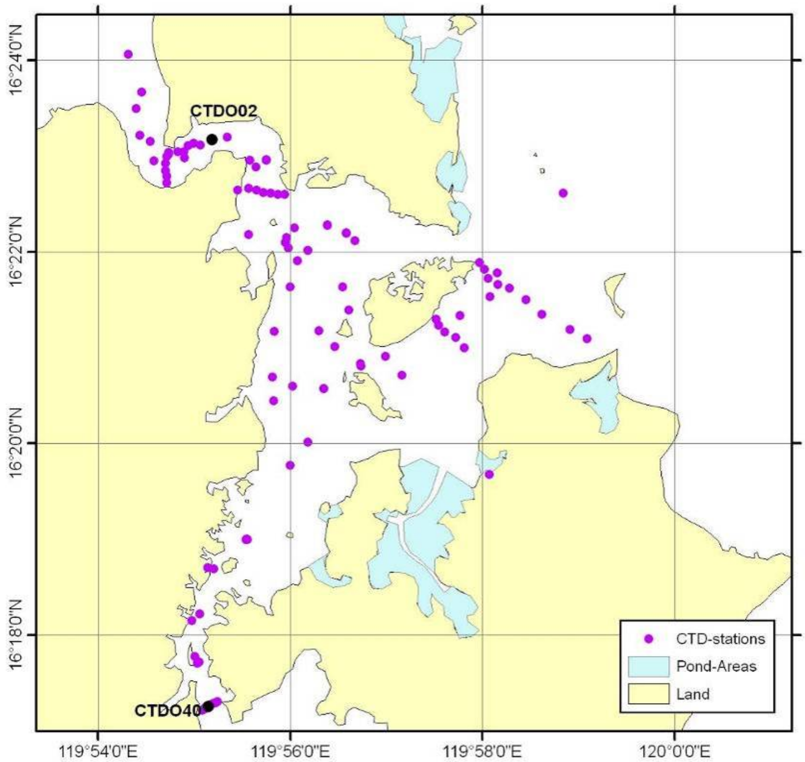


Figure 17. CTDO readings in Bolinao Bay carried out in 2005 and 2006.

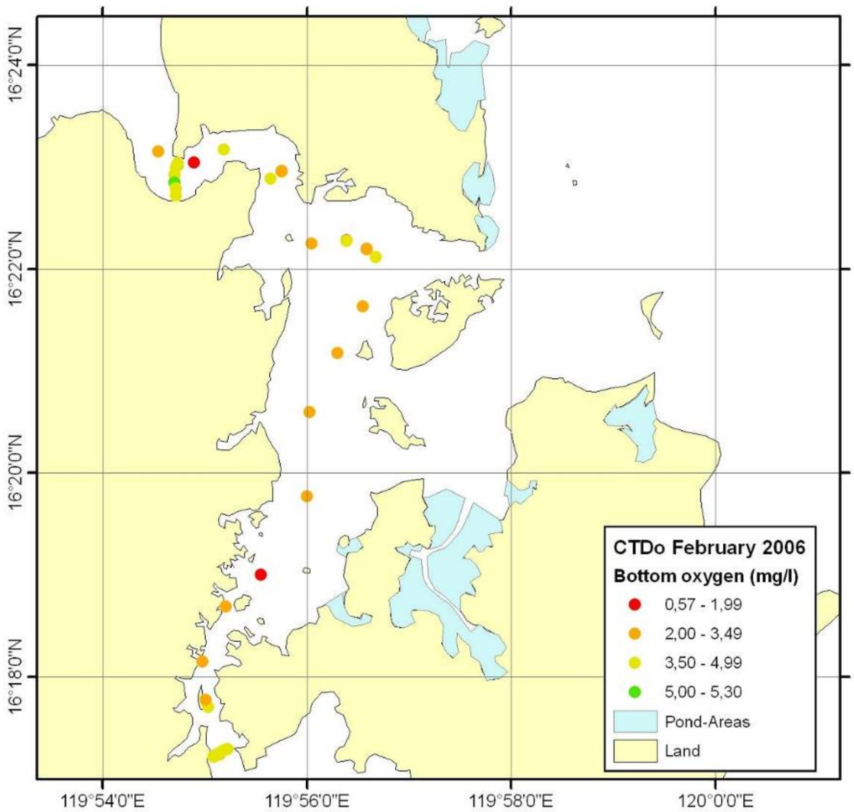


Figure 18. Oxygen levels in bottom water of the Bolinao Bay measured with the CTDO in February 2006.

CTDO-profile from station CTDO02 in the northwest entrance clearly reveals that the oxygen levels are higher below 10 meters compared to the surface water (Figure 19). The reason for this is probably that fresh re-oxygenated water is coming in from the coast with bottom currents. In areas with little water exchange the picture would have been the opposite with very low levels of oxygen close to the bottom. The profile from station CTDO40 in the southern entrance demonstrate a relatively similar profile of all the measured parameters though the whole water column. However the oxygen levels are a little bit higher in the upper layer which can be a result of input of oxygen due to wave activities in the surface water.

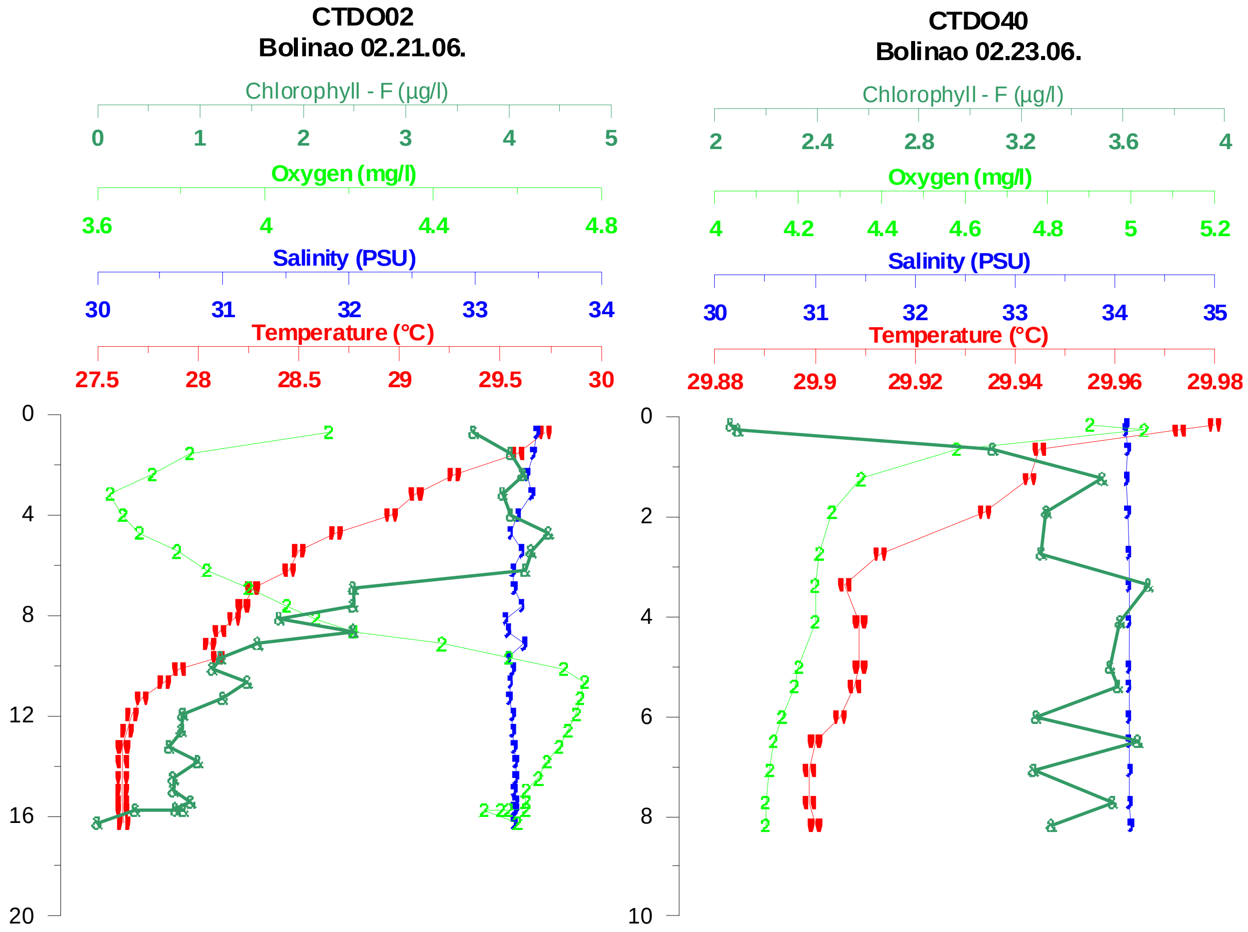


Figure 19. CTDO-profile of station CTDO02 and CTDO40 from Bolinao Bay in February 2006. Green line indicates chlorophyll, light green - temperature, blue line - salinity and red line - temperature.

2.3.3 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 are sediment samples very good indicators of the environmental condition.

Sampling was carried out with a 0.05 m^2 modified van Veen grab (Figure 20). 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 closing the grab to prevent the sediment surface being disturbed by water currents during hauling.

At each station one chemical and one biological grab sample were taken (Figure 21). Sub-samples for analyses of grain size, total organic carbon (TOC) and total nitrogen (TN) were removed from the chemical samples. Each sample was visually inspected to ensure there was no sediment disturbance. Sediment for the grain size, TOC and TN analysis was taken from the upper 2 cm layer. The samples were frozen at -20°C.

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

Each sediment sample was described with respect to sediment type, smell, colour, larger living animals and any other obvious features (i.e. visible organic layer, bacteria, feces, fish food etc.). Further samples were taken for chemical analysis, grain size and fauna analysis.

Figure 20. Illustration of the van Veen grab and picture of lowering the grab into the water.

Figure 21. Sediment sample inspected Samples for chemical analysis taken from the upper 2 cm surface.

Figure 22. Biological samples gently sieved through a 1mm round hole sieve immersed in sea water

In Bolinao all the sediment samples where evaluated visually and by smelling the sample. In areas with bad environmental conditions the sediments had high organic content and smelled H_2S (Figure 23). In these samples there was not recorded any live animals. Stations with bad sediment conditions were often related to areas with high fish farming activity (Figure 24). In areas with less fish farming there were no H_2S smell or high organic content and there were also recorded live animals.

The distribution and abundance of organisms, numbers of species and community structure were analysed as a pilot faunal registration. These measurements give good indications of the environmental state of the area. 52 samples were collected in Bolinao.

Figure 23. 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 smelling H_2S. Right picture is from an area far away from a fish cage; where the sediment is in good conditions.

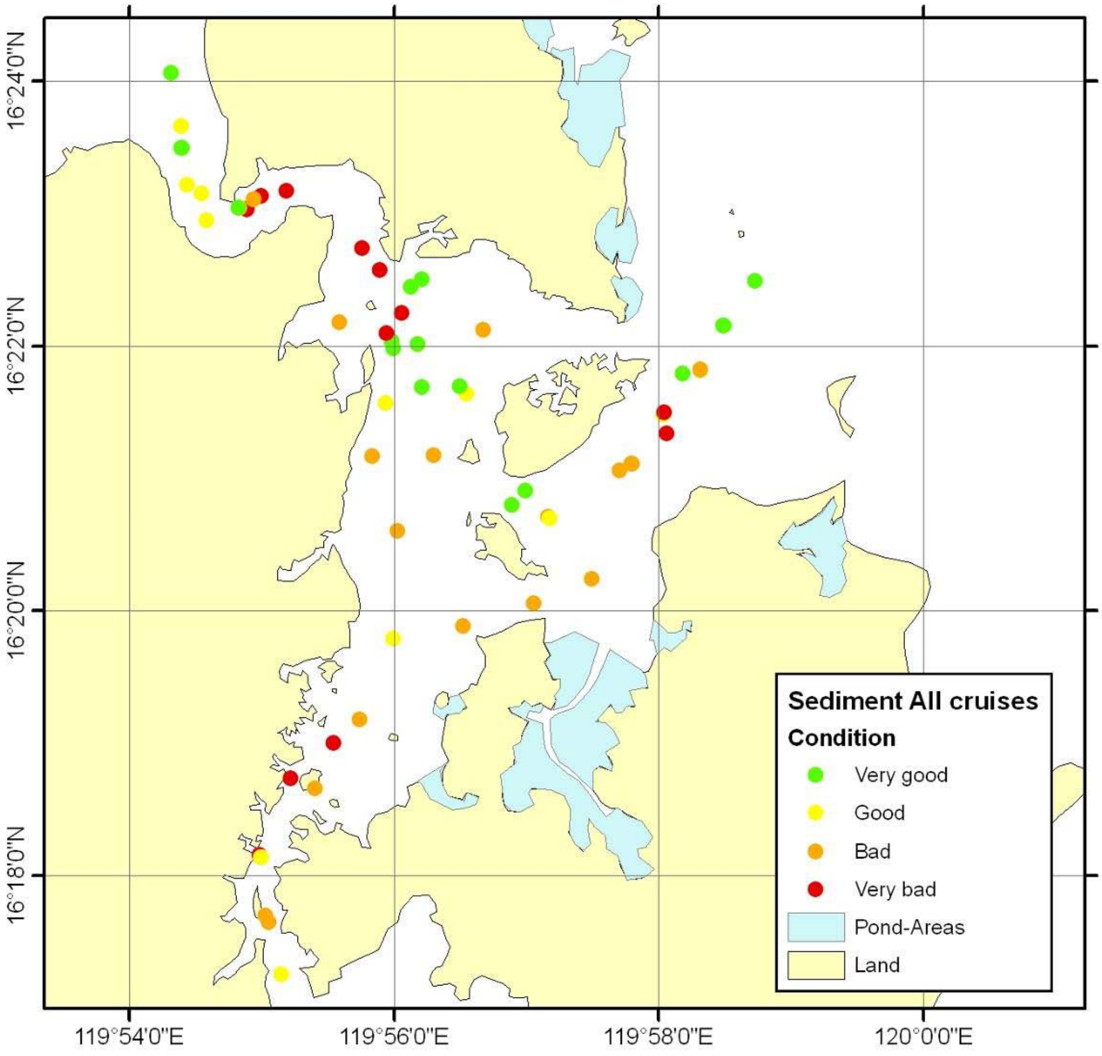


Figure 24. Illustration of the sediment conditions on 52 stations in Bolinao Bay 2005 – 2006. Green dot indicates "Very good" conditions while red dot indicates "Very bad" conditions.

3 Registration of Fish Farm structures in Bolinao

Based on the Fish farm registration and Interviews undertaken in Bolinao during April 2005.

In April 2005 there were 460 fish cages of which 322 were operational (70%) and 138 were not operational (30%) (Figure 25). The total operational fish cages have a volume of 371,910 m3 and are stocked with milkfish (98%). There are 13,652,800 fry stocked at 2g size and are grown to a market size of 433 grams in 6.8 months.

The cages are presently stocked with 11,604,880 fish with an average size of 304 grams and have a stocking density of 15.4 kg/m3. The standing stock was 3,687 tonnes of fish. The fish are fed at 2.85% per day using 103 tonnes of feed per day.

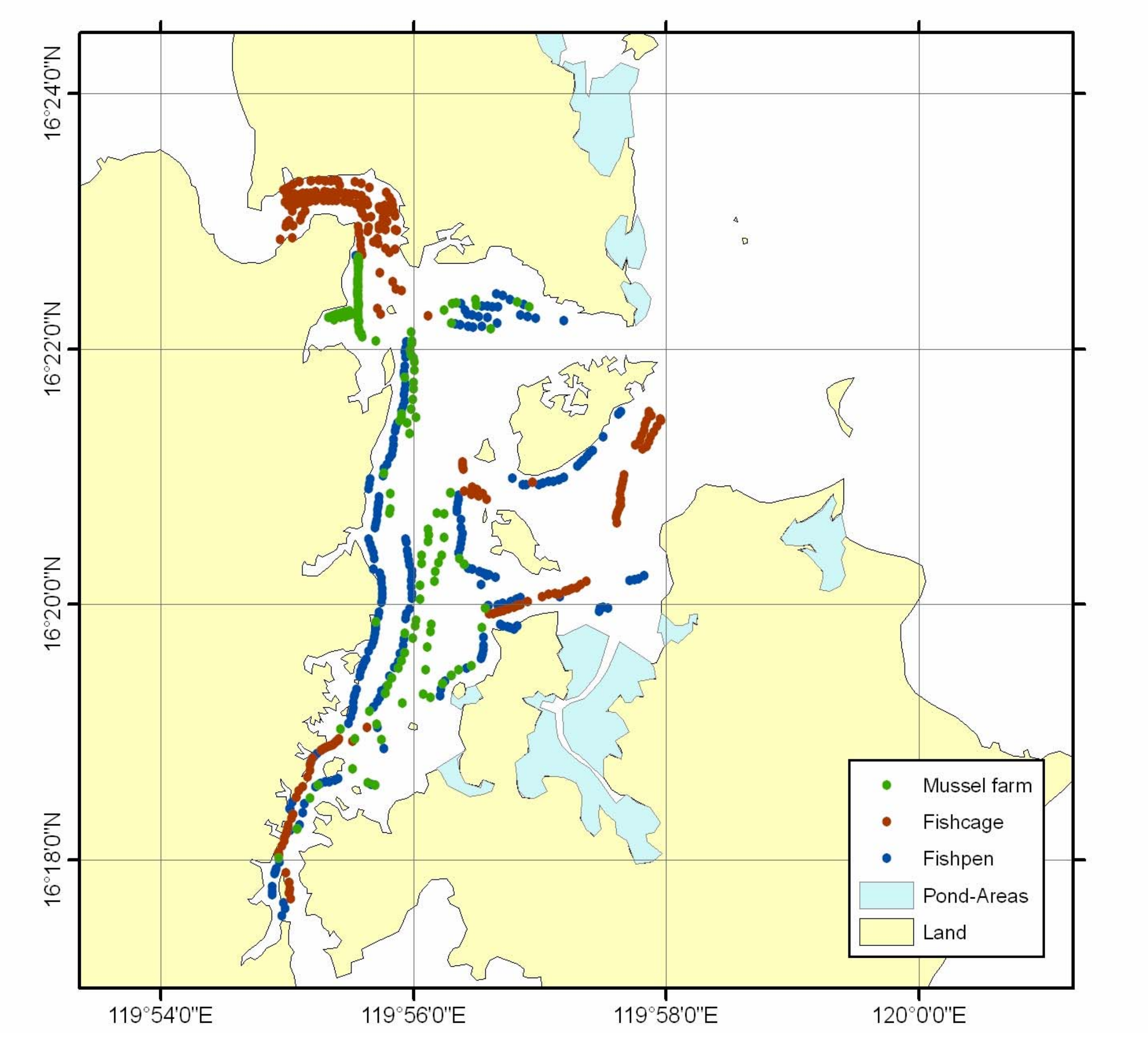


Figure 25. Map illustrating all the aquaculture activity in Bolina Bay. Green dots indicate mussel farms, red dot indicates fish cages and blue dots indicate fish pens. Light blue colorations indicate areas with fish ponds.

A production cycle from stocking fry to harvest size is 6.8 months giving 1.76 crops per year per cage. The average market size is 433 grams. The total production per cycle is 5,025 tonnes and the total production per year from cage culture is 8,867 tonnes.

There were 266 fish pens of which 217 were operational and 49 were not operational. The total operational fish pens have a volume of 3,046,029 m3 and are stocked with milkfish. There are 11,356,261 fry stocked at 2g size and are grown to a market size of 466 grams in 4.17 months.

The pens are presently stocked with 10,788,448 fish with an average size of 245 grams and have a stocking density of 1.04 kg/m3. The standing stock was 3,305 tonnes of fish, The fish are fed at 3.5% per day using 117,180 kg of feed per day.

A production cycle from stocking fry to harvest size is 4.17 months giving 2.88 crops per year per pen. The average market size is 466 grams. The total production per cycle is 5,027 tonnes and the total production per year from pen culture is 14,467 tonnes.

There are 254 mussel farms of which 253 are operational and 1 is not operational. The total operational mussel farms have 253,000 poles with a total length of 819,000 meters of pole. The production per cycle from all the mussel farms is 1,638 tonnes. There is only 1 cycle per year giving a total production per year from mussel culture if 1,638 tonnes.

In total in April 2005 there was a standing stock of 6,992 tonnes of fish giving an annual production of 23,335 tonnes of fish. During April an average of 220 tonnes of fish feed was fed per day.

There was an annual production of 1,638 tonnes of mussels (extractive species).

The sea surface area in Bolinao is 28,882,031.86 m2 (not including the islands) ie 2,888 ha.

Production is therefore there was fish production of 8.07 tonnes of fish per ha and 0.56 tonnes of mussels.

3.1 Fish cage

Interviews were undertaken with producers to determine the rage and average productivity.

Bolinao Fish Cage Range and Averaged Figures

Bolinao – Fish Cage	Range	Average
Date	16 April 2005	
Type	Fish Cage	
Net Volume	150 to 1890 m3	1155 m3
Species	Milkfish, Grouper	Milkfish 98%
Fry supply	12,000 to 80,000	42,400
Density	0.1 to 30 kg/m3	15.4 kg/m3
Present Size	2 to 400g	304g
Market size	350g to 500g	433g
Survival	85%	85%
Culture period	6 to 8 months	6.8 months
Present biomass	0.08 to 24 tonnes	11.45 tonnes
Feed given	12.5 to 575 kg/day	320 kg/day
Feeding rate	1.45 to 4.45%/day	2.85%/day
FCR	1.1 to 4:1	2.8:1

In April 2005 there were 460 fish cages of which 322 were operational (70%) and 138 were not operational (30%). The main areas for Fish cages are close to the entrances og the bay and specially in the northwest entrance (Figure 26).

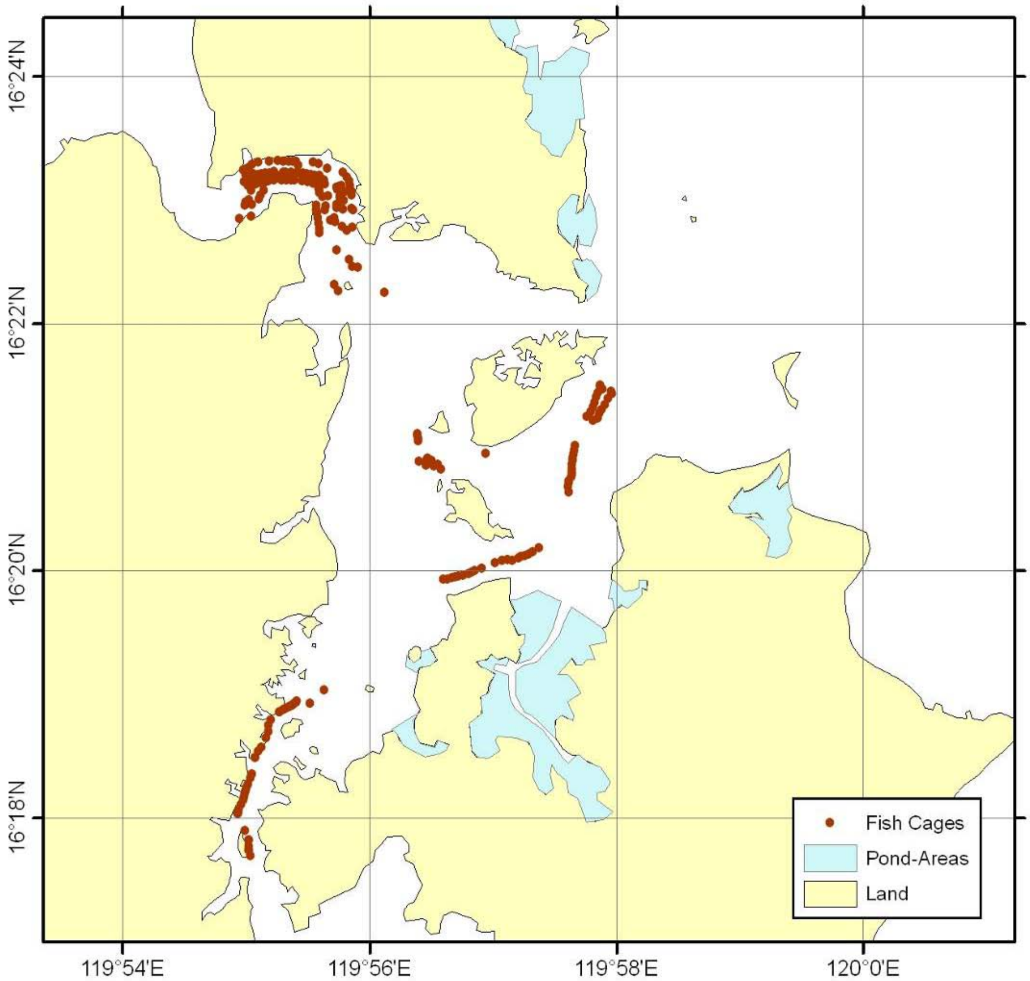


Figure 26. Map illustrating the location of fish cages in Bolinao Bay in 2005.

Average

The average fish cage has a volume of 1,155 m3 and stocked with milkfish (98%). It is stocked with 42,400 fry at 2g size and is grown to a market size of 433 grams in 6.8 months.

Each cage is presently stocked with an average of 36,040 fish with an average size of 304 grams and has a stocking density of 9.9 kg/m3. The fish are fed at 2.8% per day using 320 kg of feed per day per cage.

Total

The total operational fish cages have a volume of 371,910 m3 and are stocked with milkfish (98%). There are 13,652,800 fry stocked at 2g size and are grown to a market size of 433 grams in 6.8 months.

The cages are presently stocked with 11,604,880 fish with an average size of 304 grams and have a stocking density of 9.9 kg/m3. The fish are fed at 2.8% per day using 103 tonnes of feed per day.

A production cycle from stocking fry to harvest size is 6.8 months giving 1.76 crops per year per cage. The average market size is 433 grams. The total production per cycle is 5,025 tonnes and the total production per year from cage culture is 8,867 tonnes.

3.2 Fish Pens

Interviews were undertaken with producers to determine the rage and average productivity.

Fish Pens in Bolinao - Range and Average

Bolinao – Fish Pen	Range	Average
Date	16 April 2005	
Type	Fish Pen	
Net	12,950 to 16,000 m3	14,037 m3
Species	Milkfish	Milkfish
Stocked	45,000 to 62,000 fry per pen	52,333 per pen
Density (fry per m3)	3.5 to 3.9 fry per m3	3,73 fry per m3
Present Size (g)	85 to 400	245
Density (kg/m3)	0.3 to 1.87	1.04
Market size (g)	400 to 500	466
Survival	95%	95%
Culture period	4 to 5 months	4.17 months
Present biomass	3,820 to 30,000 kg per pen	15,232 kg per pen
Feed given	280 to 800 kg/day	540 kg/day
Feeding rate (%/day)	2.7 to 7.3	5
FCR	2.61	2.61

In April 2005 there were 266 fish pens of which 217 were operational and 49 were not operational. The areas used most frequently for fish pens are in the shallower areas close to the mainland but also close to the two Santiagio Island and Cabarruyan Island (Figure 27).

Average

The average fish pen has a volume of 14,037 m3 and stocked with milkfish. It is stocked with 52,333 fry at 2g size and is grown to a market size of 466 grams in 4.17 months.

The average pen is presently stocked with 49,716 fish with an average size of 245 grams and has a stocking density of 1.04 kg/m3. The fish are fed at 3.5 % per day using 540 kg of feed per day per pen.

Total

The total operational fish pens have a volume of 3,046,029 m3 and are stocked with milkfish. There are 10,788,448 fry stocked at 2g size and are grown to a market size of 466 grams in 4.17 months.

The pens are presently stocked with 10,788,448 fish with an average size of 245 grams and have a stocking density of 1.04 kg/m3. The fish are fed at 3.5% per day using 117,180 kg of feed per day.

A production cycle from stocking fry to harvest size is 4.17 months giving 2.88 crops per year per pen. The average market size is 466 grams. The total production per cycle is 5,027 tonnes and the total production per year from pen culture is 14,467 tonnes.

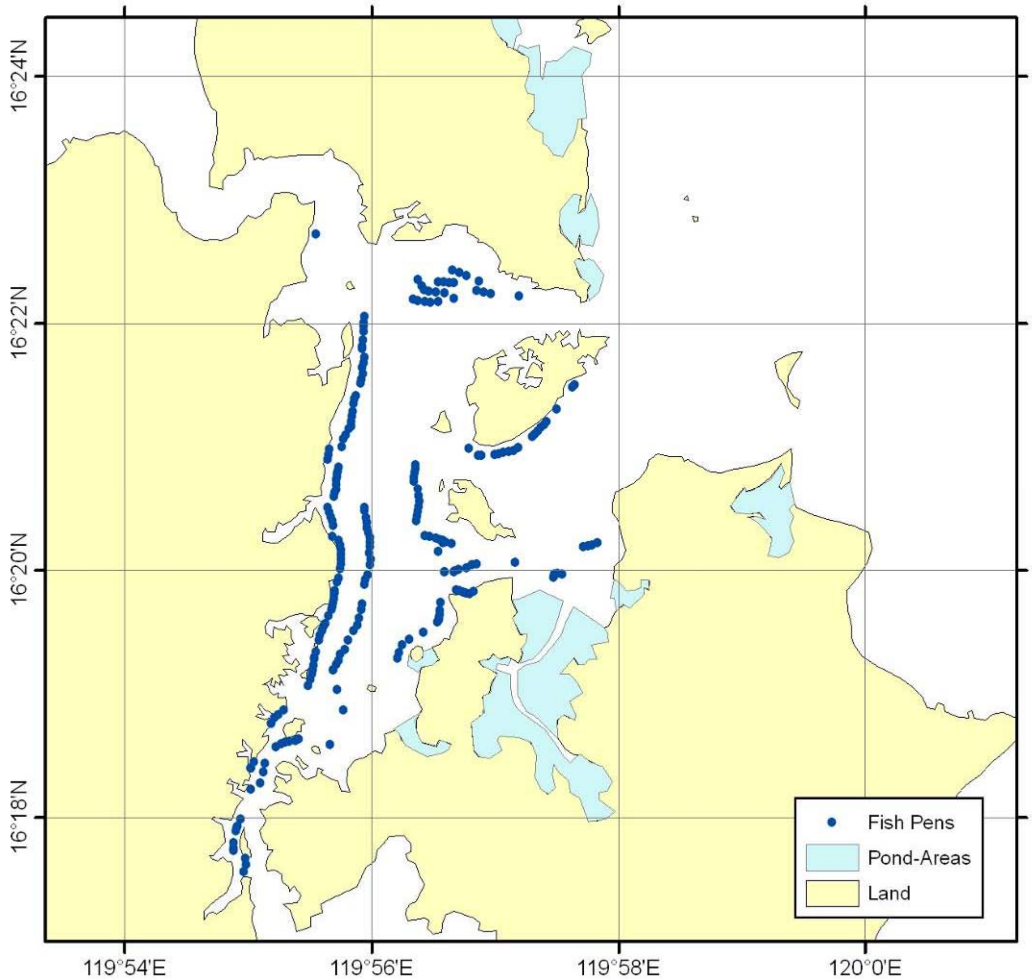


Figure 27. Location of fish pens in Bolinao Bay 2005.

3.3 Mussels

Interviews were undertaken with producers to determine the rage and average productivity.

Mussel Farms in Bolinao –Average and range

Bolinao - Mussels	Range	Average
Date	16 April 2005	
Type	Mussel	
Shape	Rectangular 30 m x 30 m	Rectangular 30 m x 30 m
Dimensions	1000 poles by 2.5 to 4 m deep	1000 poles by 3.25 m deep
Net	2,500 to 4,000 m of pole	3,250 m of pole
Species	Mussels	Mussels
Fry supply	Wild spat in rainy season	Wild spat in rainy season
Stocked		
Density		
Present Size		
Marketing	2 inch size 2 crops per year 5 to 8 kg per pole 5,000 to 8,000 kg	2 inch size 2 crops per year 6.5 kg per pole 6,500 kg
Survival		
Culture period	9 months	9 months
Present biomass		
Problems	Dive to harvest	Dive to harvest

There are 254 mussel farms of which 253 are operational and 1 is not operational. The mussel farm activity are spread out in the whole bay but the most intensive areas are in the mid an southern part of the bay (Figure 28).

Average

The average mussel farm has 1,000 poles with an average length of 3.25 meters per pole. Mussels are grown to a market size of 2 inches and there are 2 crops per year. The average pole of 3.5 m gives a crop of 6.5 kg of mussels.

Total

The total operational mussel farms have 253,000 poles with a total length of 885,500 meters of pole. The production per cycle from all the mussel farms is 1,638 tonnes. There is only 1 cycle per year giving a total production per year from mussel culture if 1,638 tonnes.

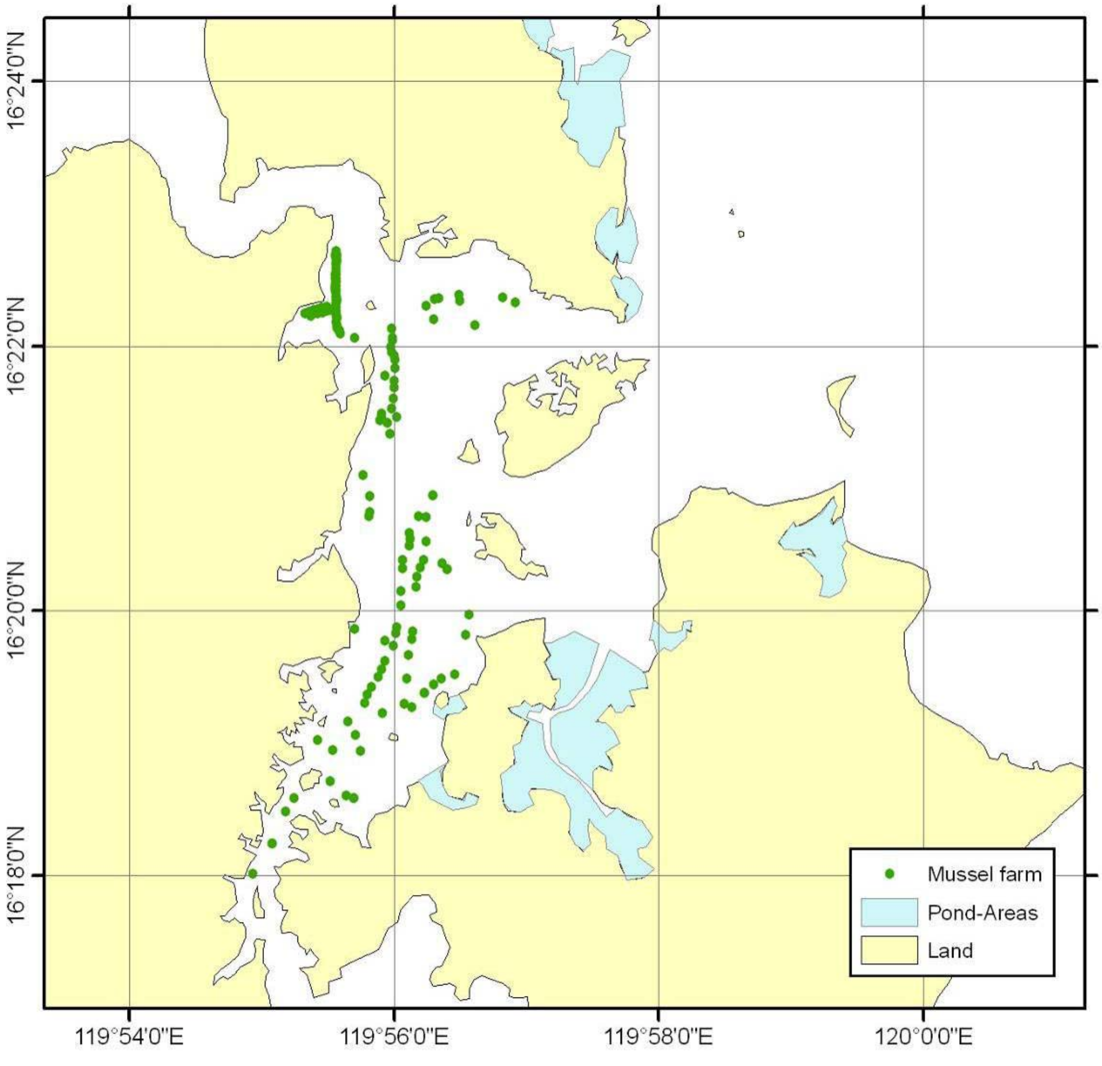


Figure 28. Location of Mussel farms in Bolinao Bay 2005.

4 Modelling carrying capacity

Surface area of 28.88 10^6 m^2 with an average depth of 4.8 m leads to the volume V= 138.6 10^6 m^3.

Residence time of particles at Bolinao, according to Magdoang and Villanoy 2006 varies from several days to over 25 days, so it would be reasonable to use 20 days.

Excretion of phosphorus from aquacultures amounts to 339 kg/day, a contribution from soluble faeces is 143 kg/day and resuspension from the bottom is estimated as 94 kg/day. Together, this amounts to 576 kg/day. (White, 2006c)

Ia = 576 (kg_P/day) / 0.05 (1/day) * 138.8 106 m3 =

83 10-6 kg/m3 = 66.5 (mg P/m3 = µg P/l)

From the Florida Lakewatch relationship between Chl-a and total P:

Log10 (µg Chl-a/l) = – 0.369 + 1.053 Log10 (µg TP/l)

we obtain the corresponding contribution to the phytoplankton concentration of
43 µg Chl-a/l

4.1 Discussion

1) Inclusion of external sources

The above contribution to phytoplankton concentration is on top of all external sources of nutrients: a) land based sources, b) concentration of nutrients entering from Lingayen Bay and c) atmospheric fall out.

If external sources were negligible or even if they are of the same order of magnitude as the contribution from fish cultures, which is unlikely, it would appear that the maximum concentration of 100 µg Chl-a/l has not been reached and hence the carrying capacity of the Bay has not been overcome.

2) Flushing of the bay

The above calculation is based on a particle residence time of 20 days which is computed from an average including neap and spring tides.

We know that the marine through flow is not constant but varies greatly. During the neap tide, flushing is much slower. If the water through flow is half the one that has been assumed, the contribution of fish cultures alone would get close to natural carrying capacity. Then the inclusion of all external nutrient sources would well overcome the carrying capacity.

According to the existing information, this has already happened at the neap tide, which is characterized by the lowest through flow.

3) Distributed residence time of water

Not all parts of the bay exchange water with Lingayen Bay equally fast. Parts of the bay close to Lingayen Bay between Santiago Island and Cabarruyan, and especially water close to Guigiwanen strait have the residence time down to one day. Contrary to that, waters close to the east coast, opposite of the Siapar Island, have residence time in the bay of more than 25 days. This tells us that the average value for the carrying capacity does not mean much, and that a more meaningful approach would be to compute carrying capacity for different parts of the bay. Such an approach implies that a spatial resolution must be taken into account. Two dimensional discretisation seems an obvious choice, however the depth of the bay varies almost 20 times with the deepest part close to Guigiwanen strait.

Figure 29, represents bathymetry as measured during the project including earlier data.

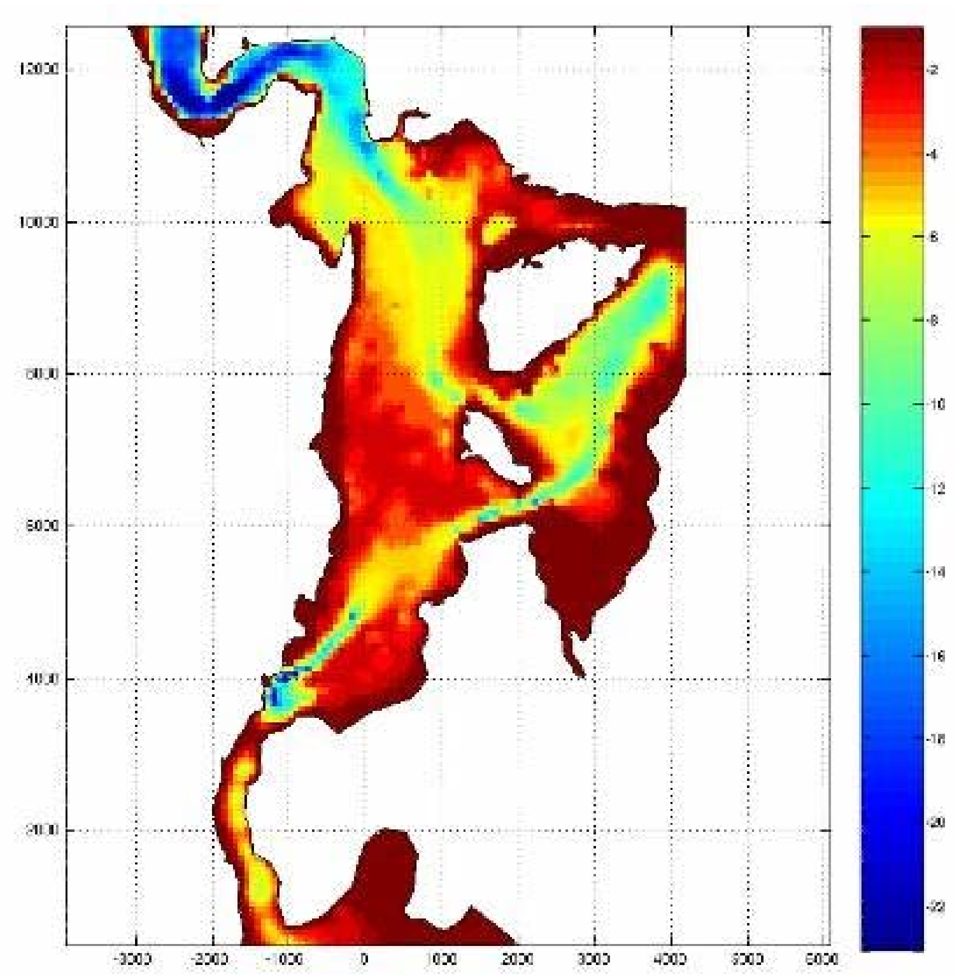


Figure 29. Bathymetry of the Bolinao Bay. Distances are in meters. The depth is color coded between 2 m (red) and 22 m (blue).

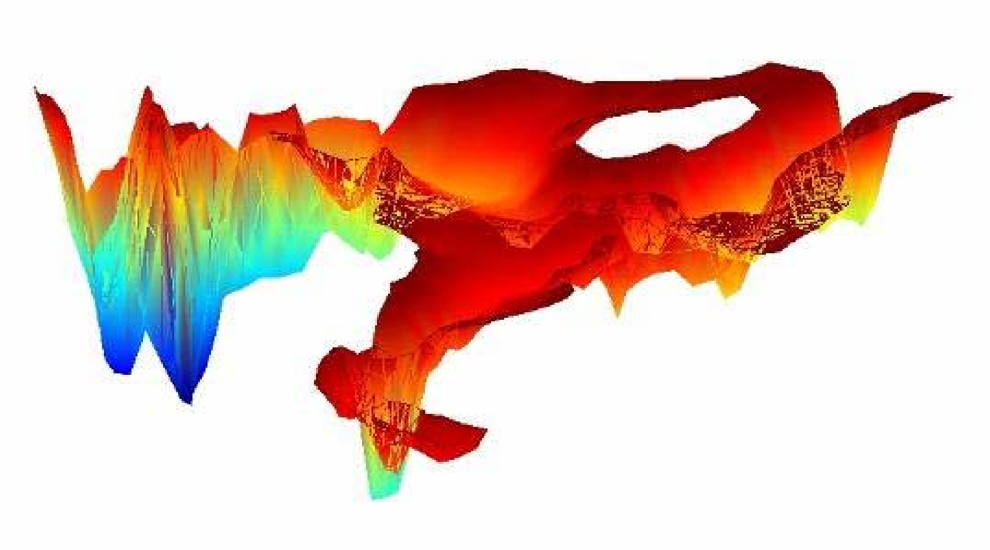


Figure 30. Three dimensional drawing of the bathymetry.

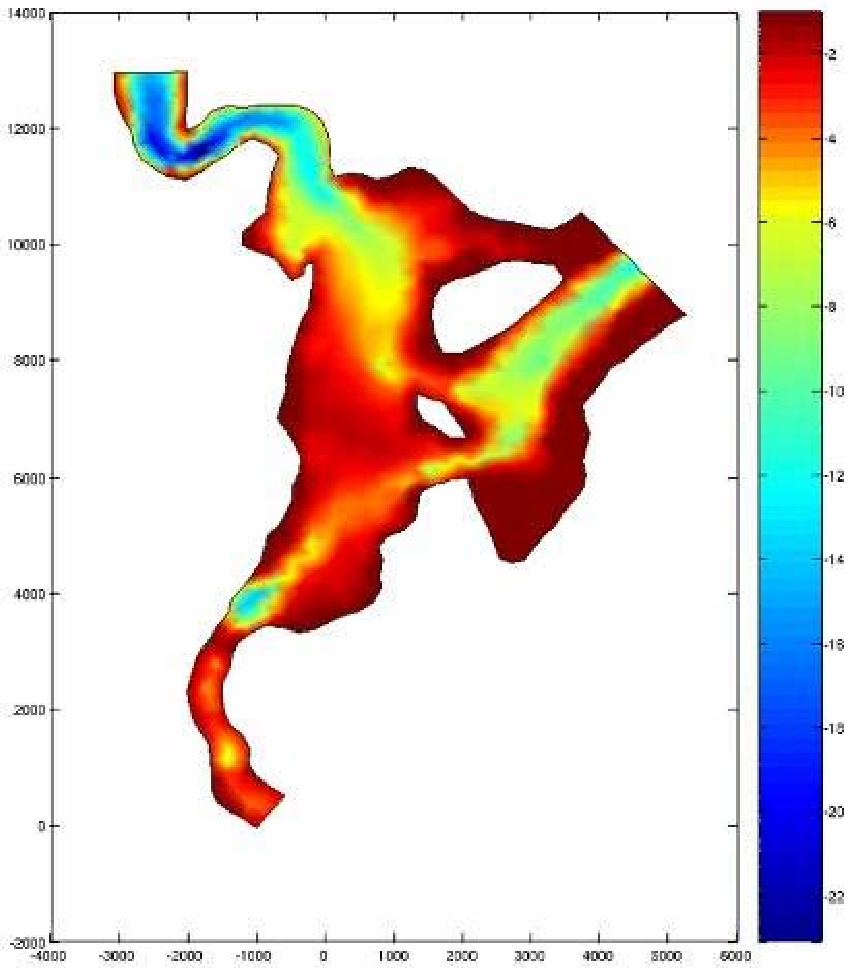


Figure 31. Numerically smoothened bathymetry.

While moving through the bay, at shallow locations and especially at areas with developed coral reefs, water encounters more friction and hence it goes slower. According to Reidenbach et al. (Limnol. Ocean, 51, 2006) in such areas we expect the friction coefficient to be about 2.5 higher than in the rest of the bay.

Figure 32 shows areas with assumed higher friction coefficient.

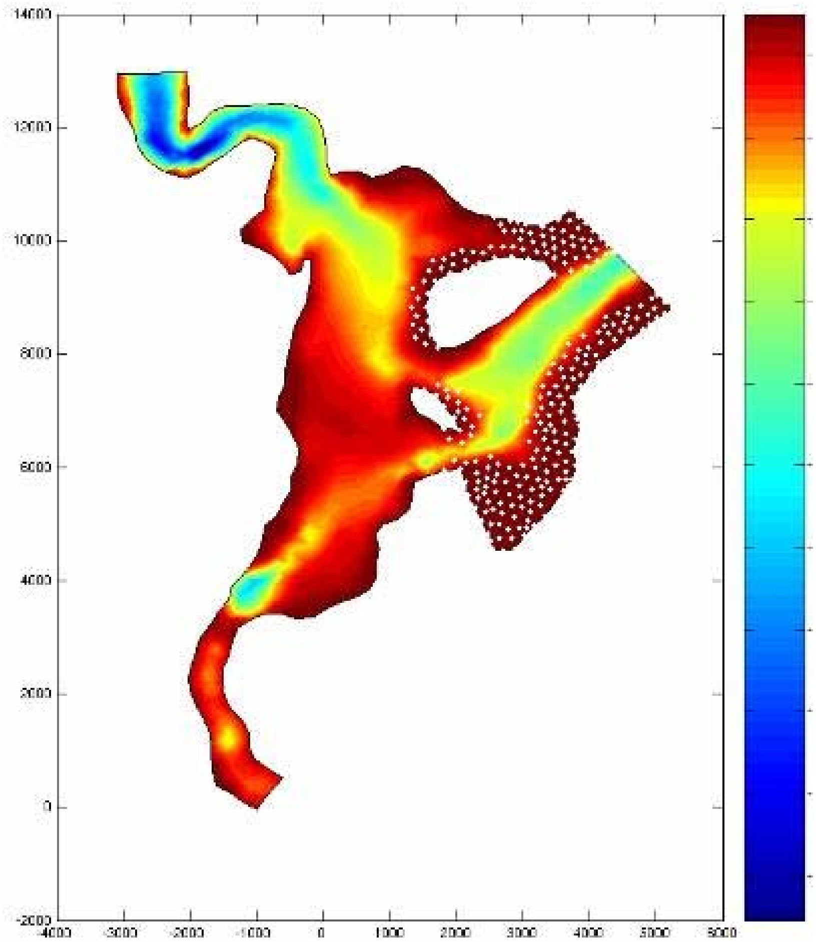


Figure 32. Areas with higher bottom friction coefficient are denoted with dots.

In order to calculate movement of water we have divided the bay into triangular prisms with variable depth. Using this division, we have run a hydrodynamic model. The tops of the prisms are triangles. Figure 33 shows how the prisms cover the surface of the bay. The prisms are of variable density: finer diviion is necessary in straits.

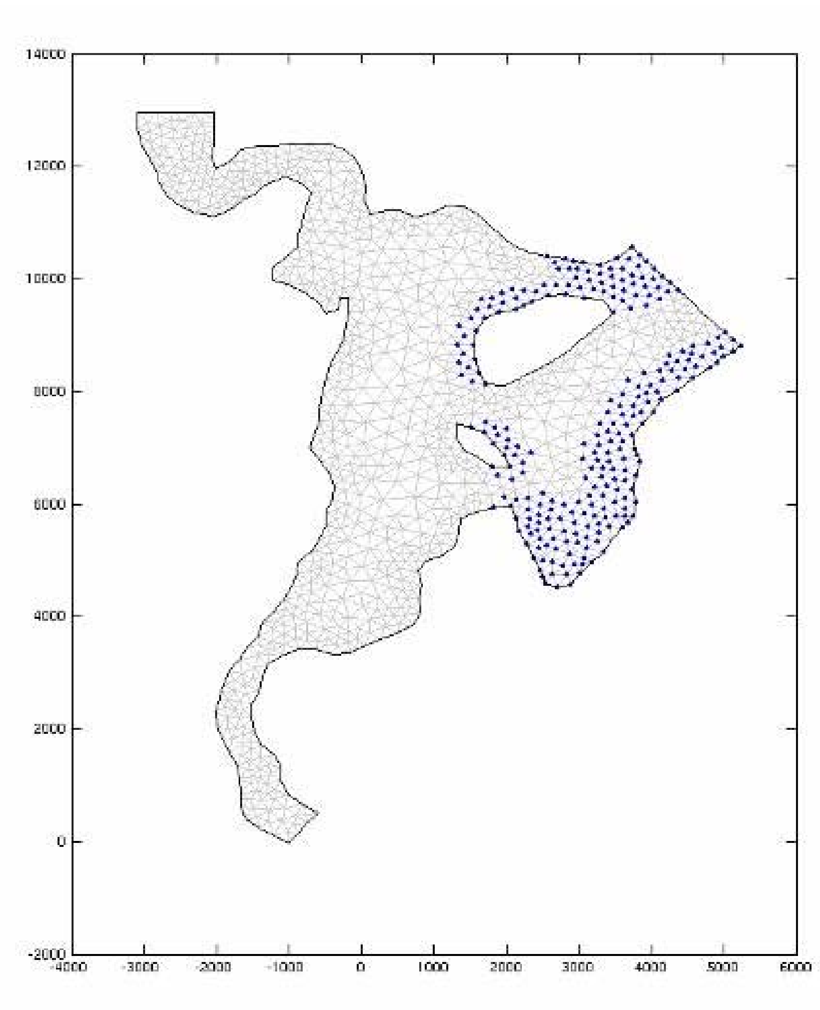


Figure 33. The divisions show triangles which represent tops of prisms that extent to the bottom. Areas of higher bottom friction coefficient are also shown.

The hydrodynamic model has been run with known tidal elevations on all three boundaries. Four tidal constituents are used: K1, O1, M2 and S2. It is necessary to state that tidal elevations are not in phase at all three openings in the Bolinao Bay. A run is displayed from 9 to 26 February 2006. This time interval is chosen since currents were measured between 21 and 24 February 2006 and this offered an opportunity to compare computed with measured currents.

The comparison for the station no. 31 is shown in Figure 34.

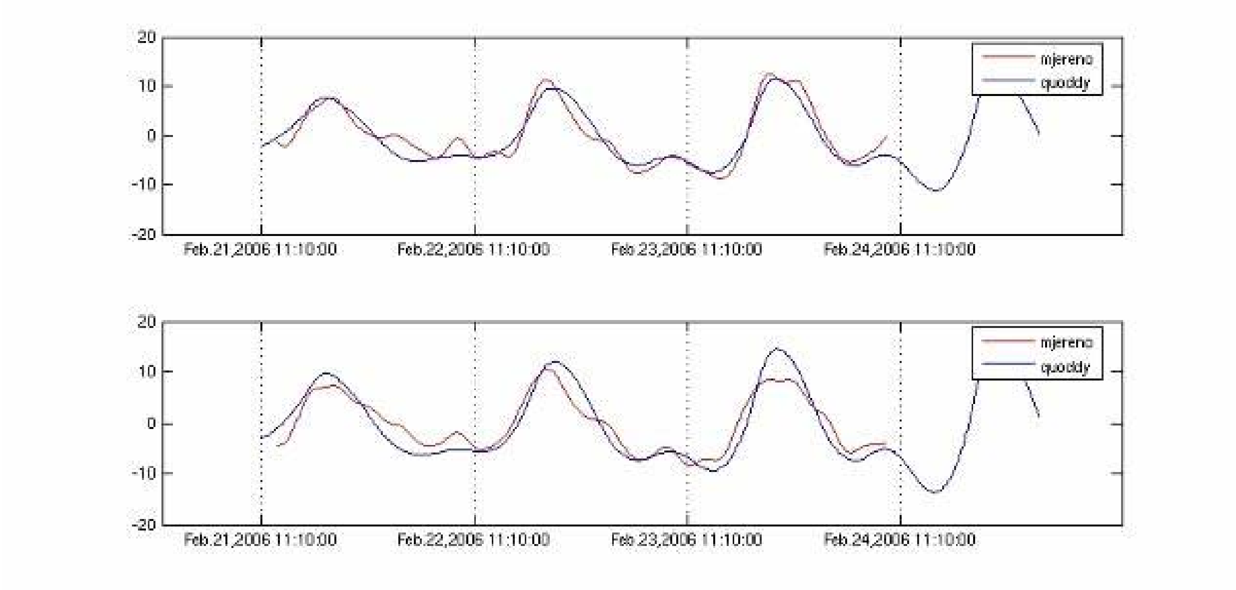


Figure 34. Measured and computed currents at the station no. 31 from 21 until 24 February 2006. The East component of the vector is shown in the figure above and the North component is shown in figure below. Computed current is shown in blue and measured in red.

Movement of water for a given period is obtained as a movie. One snapshot of the evolution of the current field is shown in Figure 9.

Current field, which in our case has horizontal and vertical variability, is needed to compute transport of particles. However, transport can not be computed on the same numerical mesh as water movement. Instead a quadruple density of mesh is needed.

Figure 10 shows the numerical mesh used to compute transport of water particles in the bay.

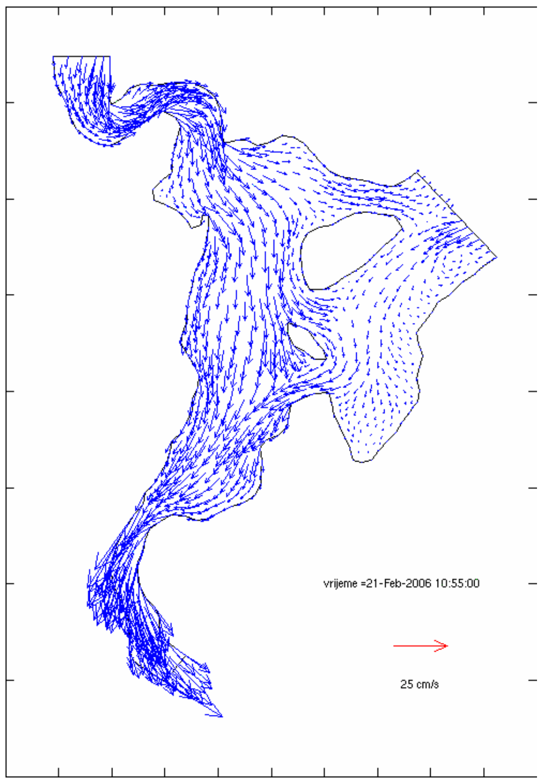


Figure 35. A snapshot of the obtained current field. The current field is displayed for 21 February 2006 at 10 h and 55 min.

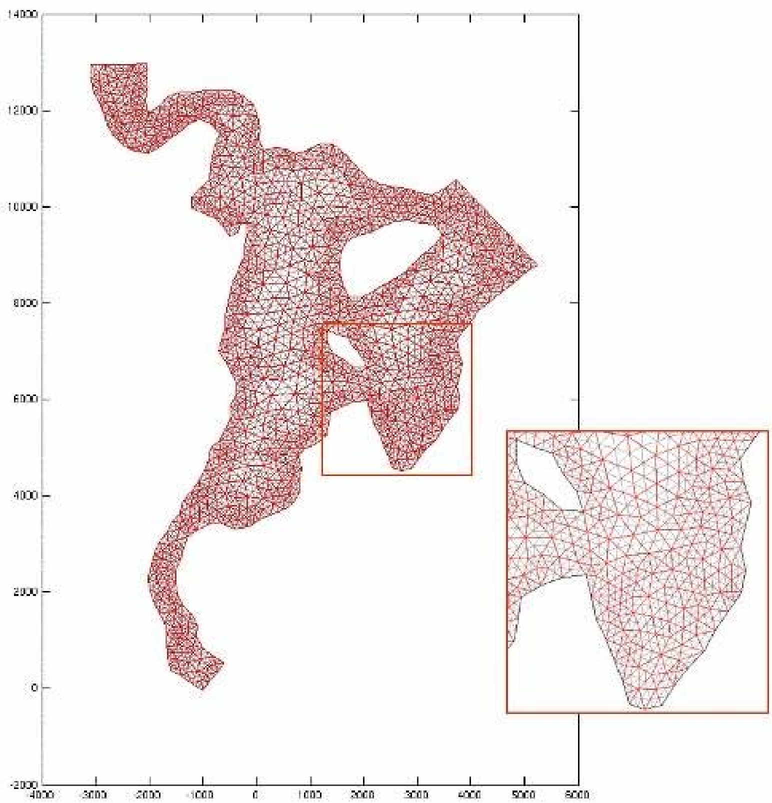


Figure 36. Numerical mesh for calculation of transport. Each prism used in the hydrodynamical model has been divided into four prisms. This is better seen on the square which is shown separately.

During current measurements, drogues were also released. This offered a possibility to compare computed movement of water with movement of drouges.

Figure 37 shows a comparison at the station no. 31.

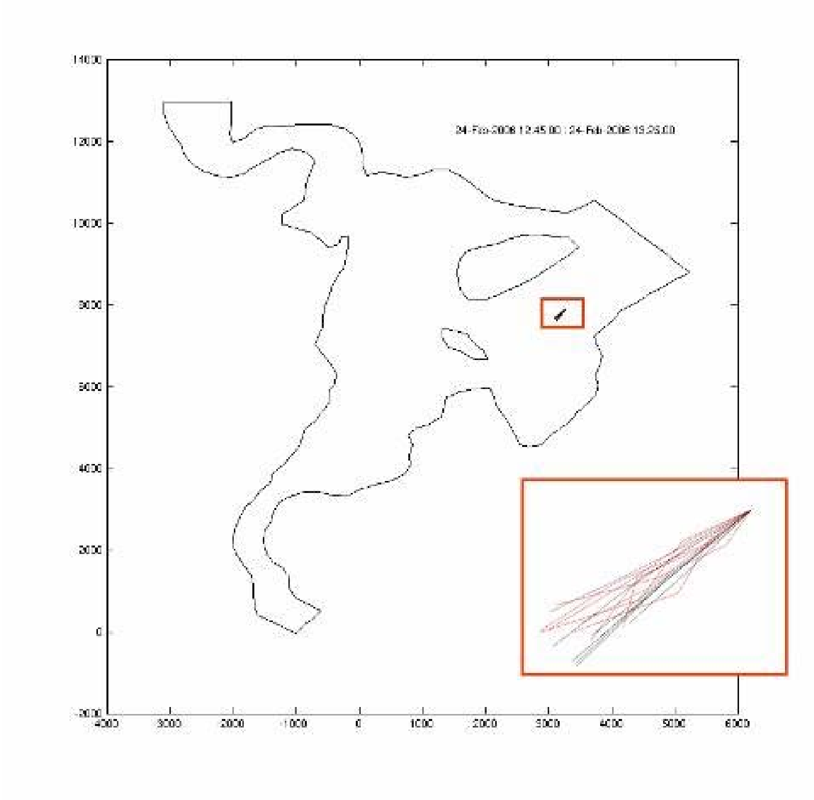


Figure 37. A comparison of movement of drogues (black) and model (red). At the station no. 31, drogues were released on 24 February 2006 at 12 h 45 min and collected at 13h 25 min.

Good agreement between model results and measured data (not only at the station no. 31 but also at other measurement stations, encouraged us to investigate movement of water particles released at various positions in the Bay and record times when they leave the bay. Results of a numerical experiment in which three "water particles" were released are shown in Figure 38. Note that during 17 days none of the three particles succeeded to leave the bay.

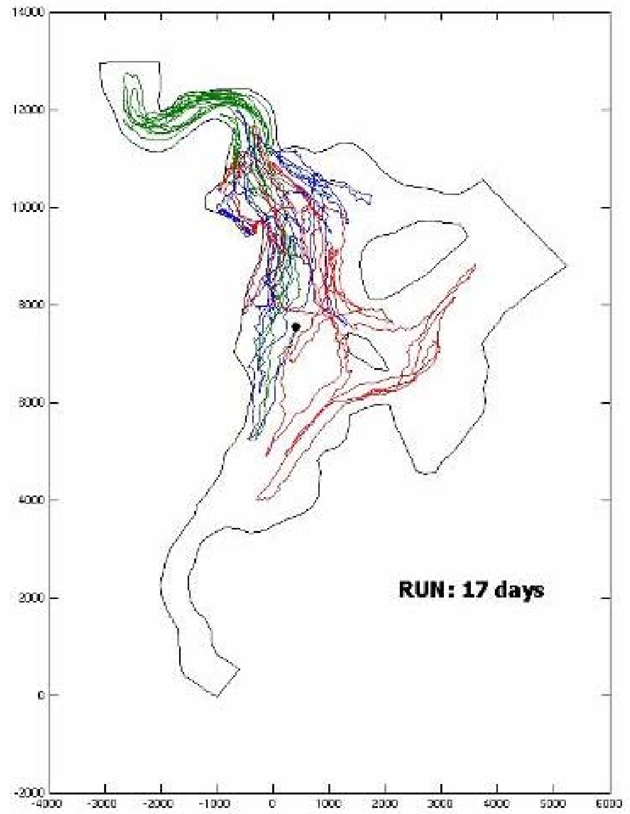


Figure 38. Paths of three "water particles" released in the model from the black dot. Paths of the three water particles are colour coded (red, green and blue).

To answer the question of how long it would take a particle to leave the bay when released at any location in the bay, we need another approach. The integration run for 35 days gives results found in the Figure 39. We see that particles close to the openings leave the bay within a day or two while particles released in the central-east side of the bay, take as much as 30 days. Finally, there exist particles which do not leave the bay even after 35 days. However, these locations are very few. Locations of very long residence times of water particles mean small carrying capacity.

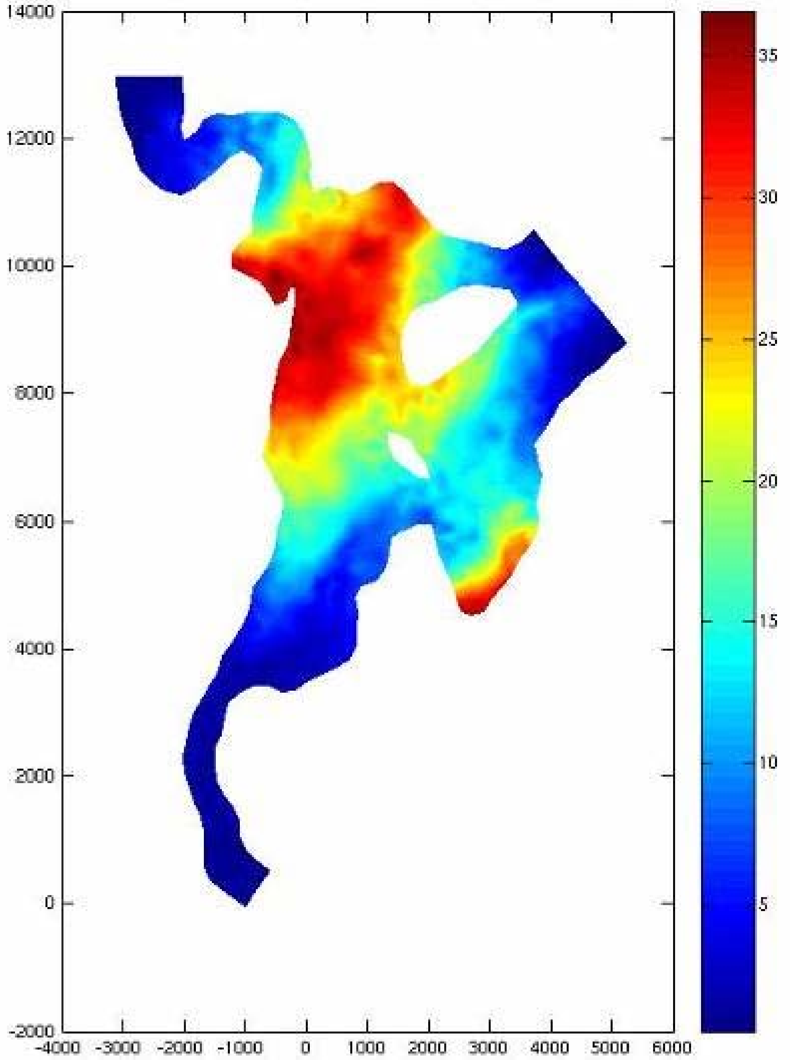


Figure 39. Residence times of particles released at every location in the bay. X and Y coordinates are in meters. Residence time is color coded from 5 days (blue) to 35 days (red).

5 Recommended management measures

The assumption here is that fish kills occur due to lack of oxygen consumed by high concentration of phytoplankton during several consecutive overcast days.

A. Measures within the fishfarming community

1. Polyculture of fish and shellfish

Installing additional shellfish cultures is a useful measure that has two functions: a production of fish and shellfish may be increased in parallel. Shellfish consume phytoplankton and hence the critical phytoplankton concentration can not be reached easily. Cconsequently, the probability of hypoxia during overcast days is decreased. This means that the carrying capacity for fish cultures increases.

It looks as if there is no end to this measure: by increasing shellfish production one increases fish production and increasing fish production gives a base to increase in shellfish production.

However, if one goes to far with this measure other problems will appear:

a) fish and shellfish both consume oxygen, so sooner or latter, they will run into oxygen deficiency. But before that happens,

b) the phytoplankton which is avoided by shellfish will produce a bloom. These phytoplankton species will find themselves in the nutrient rich environment with significantly decreased competition from other phytoplankton that had been taken by shellfish. The result will be a massive phytoplankton bloom possibly of a toxic phytoplankton. This bloom may cause a simultaneous fish and shellfish kill.

Hence, this measure may not be increased very far beyond natural carrying capacity.

c) Finally, fish and shellfish cultures need to be separated from each other by an optimum distance, and this will limit both aquacultures.

2. Changes in the feeding strategy

Changes toward optimum feeding strategies are necessary since it has been found during this project that caretakers overfeed fish. By feeding less they will decrease the cost and hence increase the economic benefit. Furthermore, they will decrease impact to the environment and hence increase carrying capacity or reduce risk of fish kills.

3. Redistribution of fish and shellfish cultures

For optimum production i.e. maximum production with minimum impact to the environment, one needs to consider redistribution of fish farms. The best location for a fish farm is at the position of higher currents and inflow from outside the bay preferably close to the opening toward Lingayen and opening toward Bolinao city. However, crowding to many aquacultures there, increases resistance to the movement of water in, and out of the bay, and hence reduces carrying capacity inside the bay. Perhaps the best solution is to locate shellfish cultures inside the bay where there exists the longest residence time of water and where the highest density of phytoplankton is expected.

4. Early waning systems

Due to the tides there are times during the tidal cycle that flushing of the bay is reduced dramatically. During these periods, there is greater risk from low oxygenation, build up of nutrients and algal blooms.

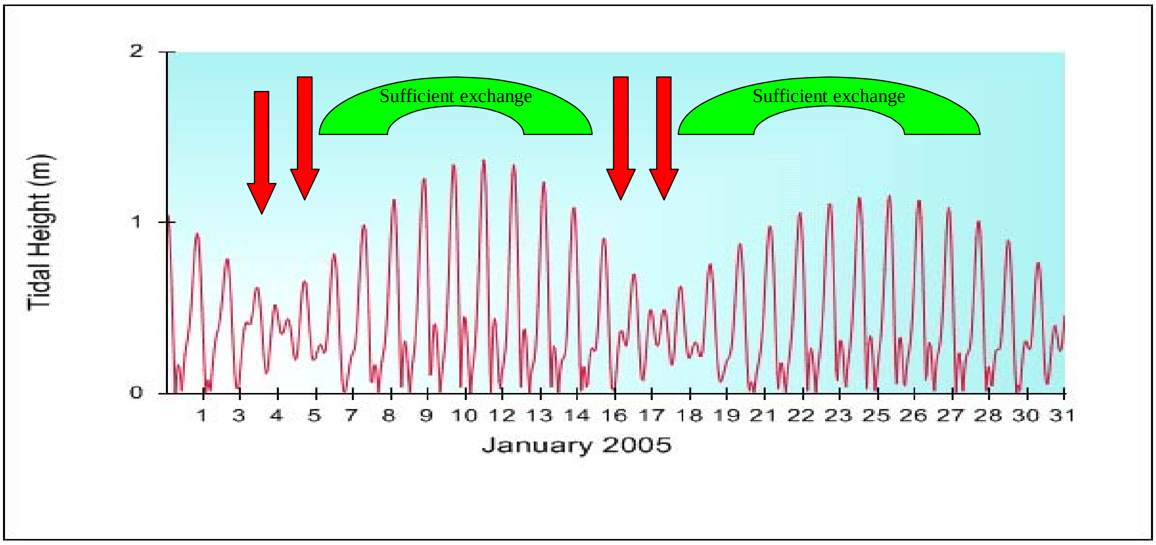


Figure 40. Periods during the month where there is sufficient exchange of water in the bay and periods when there is less exchange and greater risk.

If low exchange occurs at night there is even greater risk from low oxygenation and so fish should not be fed the day before these risk periods and if possible fish harvested from the cage to reduce stocking density and biomass.

As tide tables are available on year in advance, these tidetables can be analysed and a prediction made of the days with higher risks.

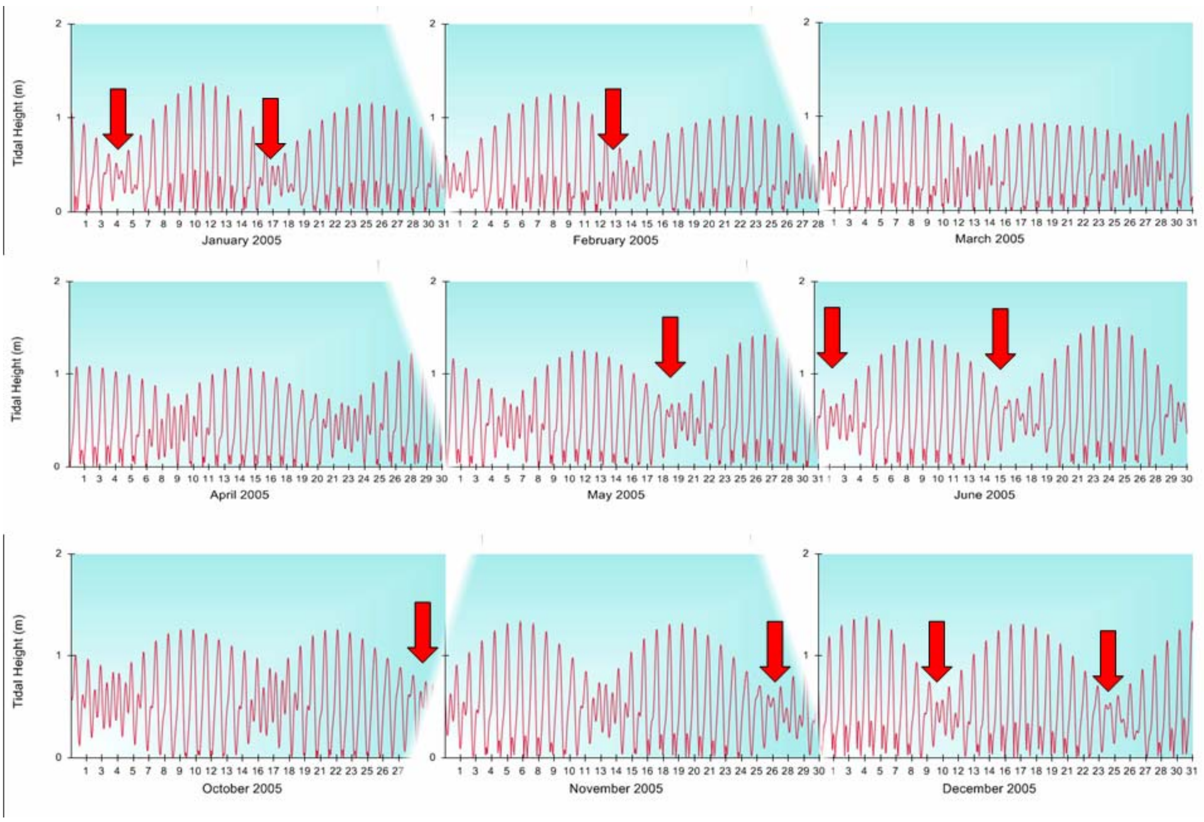


Figure 41. Tidal cycle through the year showing periods of highest risk

Risk periods in Bolinao can then be identified as

- 3 and 4 January
- 16 May
- 1 to 3 June
- 15 June
- 10 December
- 25 December

If these dates are analysed further critical times can be identified

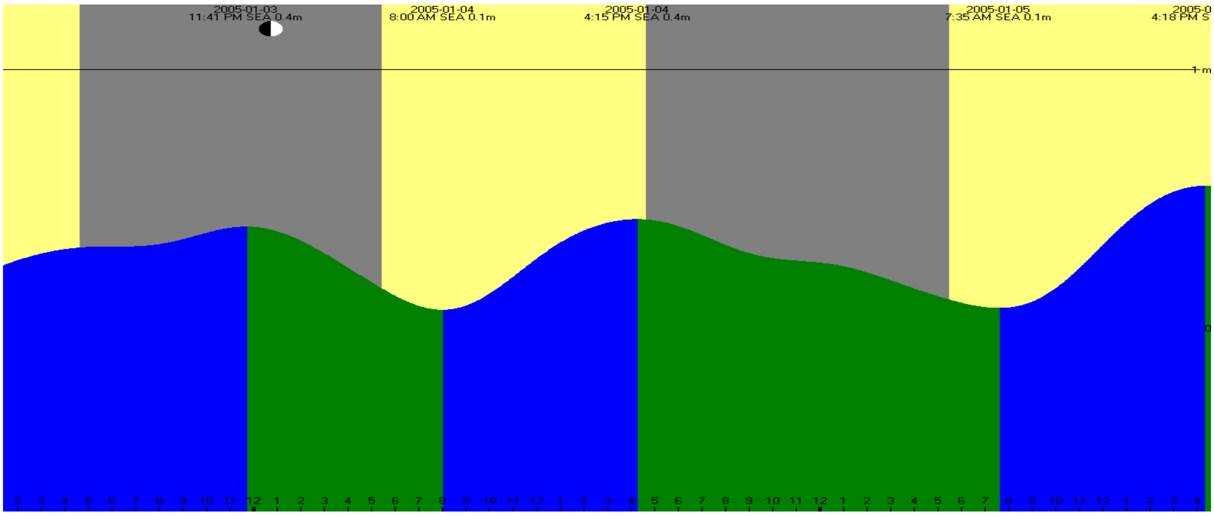


Figure 42. Tidal cycle on 3 and 4 January.

It can be seen from Figure 42 that the tides vary only 20 cm over 12 hours during the night. If there is high algal levels, high fish biomass, then oxygen levels during the night will reach critical levels.

This can be compared with the very low tidal difference occurring on 1 and 2nd June

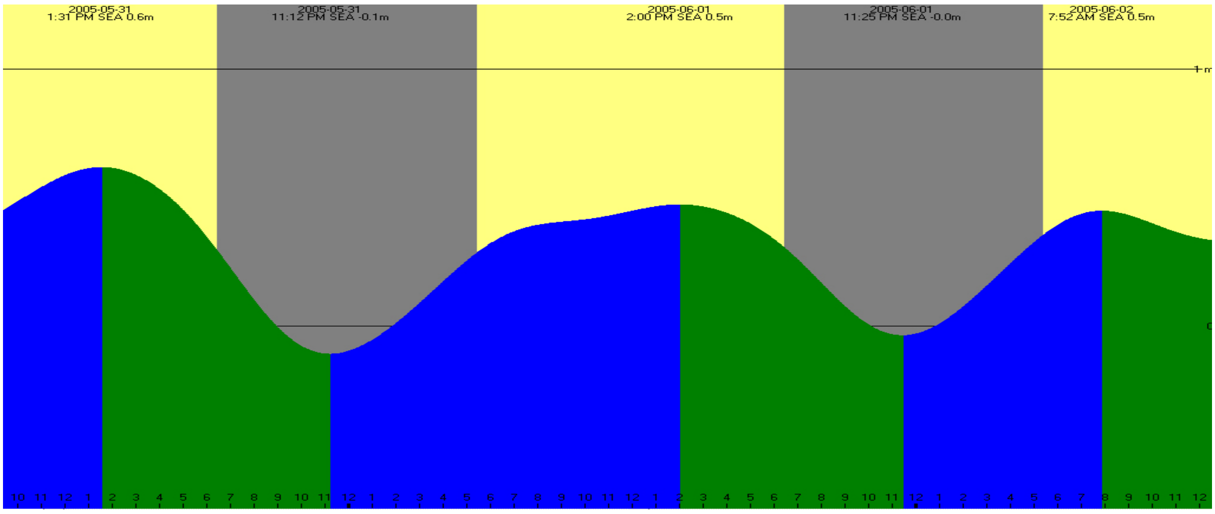


Figure 43. Tidal cycle on 1 and 2 June

The low tidal difference of 10 cm over a 12 hour period occurs during daylight when algae are producing oxygen so even with low tidal refreshment, there should be sufficient oxygen for the fish.

If future tide tables are analysed in this way, an early warning calendar can pre prepared in advance showing risk periods and critical risk periods.

B) A measure outside fish production community

4. Reduction of nutrient inflow
Wastewaters from cities and villages should be processed wherever possible using biological reactors which are able to remove organic matter and nutrients.

The more wastewater that is processed, the better, since a decrease of nutrient inflow is directly proportional to the increase in carrying capacity of fish aquacultures.

6 Participatory Workshop

A participatory workshop on Environmental Monitoring and Modelling of Aquaculture was undertaken in Bolinao on 24 – 25 November 2006

Part I. Implementors and planners Workshop
Date: 24 November 2006

Composition of participants:
- Local government: agriculturist offices, barangay LGU, municipal LGU
- Academe: MSI-UP
- Government agencies: BFAR and DENR
- NGO: KAISAKA Inc. BOMEFFI

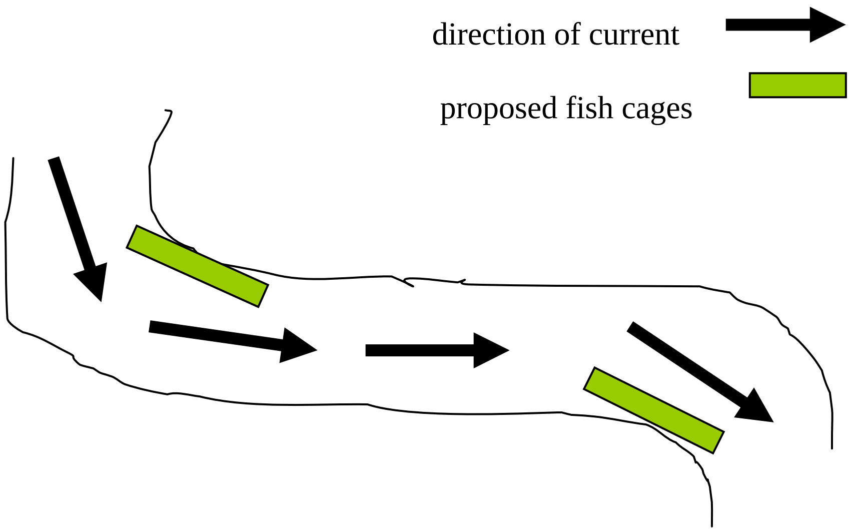
Total no of participants: 33

Discussion:

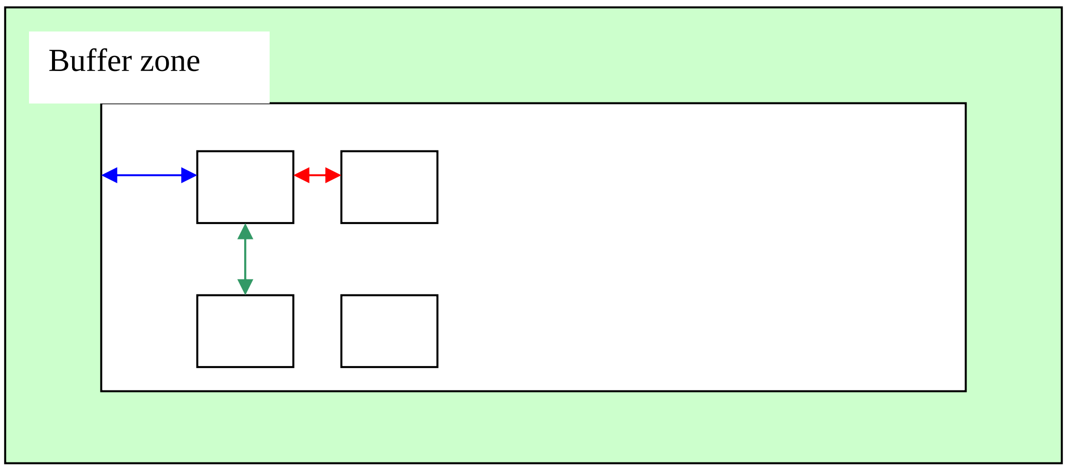
1. Inquiry on the effect of excess feeds on corals and seagrasses.
   Sediments/mud from excess feeds can smother the seagrass beds thus decrease its growth rate. High turbidity of the water, lowers the photosynthetic activity. Studies have shown that the nearer the aquaculture farms, the greater is the impact to the ecosystem. Some measures that can be considered to lessen the effects of aquaculture are optimization of FCR and establishment of buffer zones around the farms.

2. One fisherman has suggested the conduct of pilot project in Lucero on proper stocking and distance between cages. The pilot project can be awarded to a fisherman's organization through bidding, on the basis of good management practices and policies being proposed by the proponent organization.

3. Proposed demonstration farm in Lucero:

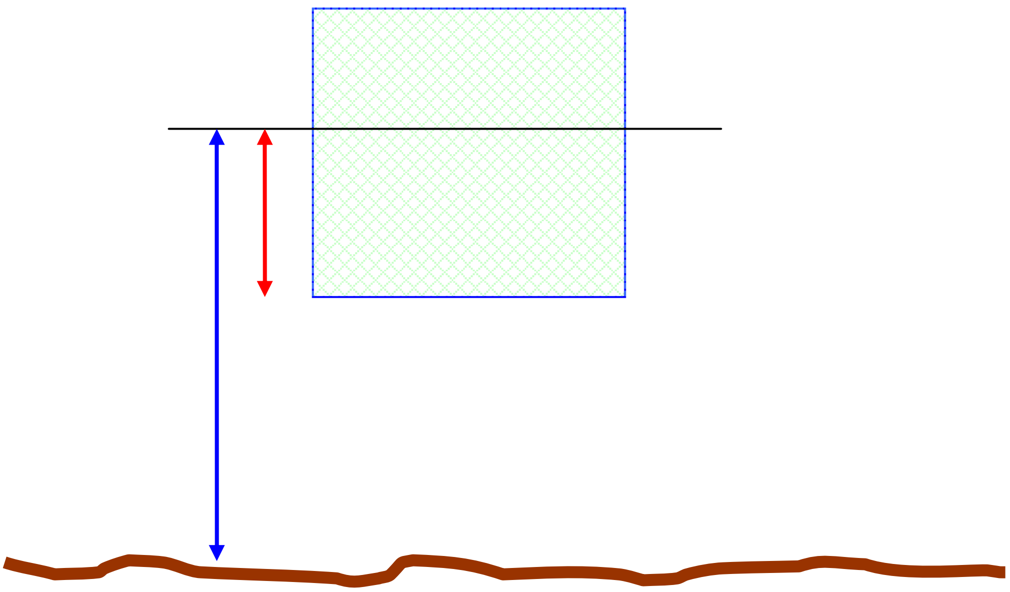


4. Proposed Farm design



- No/negligible impact outside the area of the farm (outside of green zone). The aquaculture zone can be established 150 meter away from the nearest sensitive habitat.
- 20 meter buffer from the zone (blue arrow), 1 meter distance between cages (red arrow) and 50 meter distance between rows of cages (green arrow)
- The total density can be 300 tons, i.e. 30 cages and 10 tons each)

5. Proposed depth of cage. The depth of cage, ideally, should be 1/3 (red arrow) of the total water depth (blue arrow)



6. A copy of the data collected under this project will be given to the Technical Working Group. Continuous collection of information current speed and direction and sediment

7. Moving out of bigger farms to offshore areas can be explored.

8. Putting up of shellfish farms in between cages to reduce nutrient loading. Suggested design is 1 kg of shellfish culture: 2 kg of fish. This can increase the stocking density of fish by 14%.

Part II. Stakeholders Workshop

Date: 25 November 2006

Composition of participants Annex C):
- Local government: agriculturist offices, municipal and barangay LGUs
- Government agencies: BFAR
- Academe: MSI-UP
- Fishpond operators, people's organization

Total participants : 31

Action Plan:
1. Improvement of FCR
   It was proposed to hold a "Training of trainers" on "Improved feeding and techniques" and "Mussel raft operation techniques"

   Date: March 16, 2007

   Target number of people: 20-25

Target persons: core group of caretakers, LGU (3 persons), NGO, UPMSI (2), Water quality monitoring group

APN will provide the training materials while LGU will be in charged with the venue and food

2. Integrated aquaculture: shellfish and finfish
   - Zoning of the bay for mussel culture
   - Alternate shellfish culture and fish cages

3. Collection of historical data for chlorophyll-a (c/o Dr. McGlone, UPMSI) and meteorological data (c/o NIFTDC-BFAR) in order to determine the optimal areas for the location of mollusc farms and to determine potential offshore sites.

4. Putting up of cages outside the mouth of the bay. An experiment on determining the ideal distance of fish cages from offshore areas can be explored. Once this has been determined, then larger farms with more robust cages to be encouraged to relocate to these more exposed areas that have better flushing characteristics.

5. Regulation on licensing can include giving of incentives to mussel farm operators and giving sanctions on violators of cage spacing and stocking density.

6. Depth of cages. Depth of cage should be no more than 1/3 of the total water depth.

Annex 1. Contact list of persons attending Implementors and planners Workshop on 24 November 2006

captbolinao – lgu@yahoo.com c/o Jojo → contact person (LGU - Bolinao) for the Training of trainers

REGISTRATION FORM

Presentations and round table workshop on
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Date: Nov. 24, 2006

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Annex 2. Contact list of persons attending stakeholders Workshop on 25 November 2006

REGISTRATION FORM

Presentations and round table workshop on
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