Recommendations for practical measures to mitigate the impact of aquaculture on the environment in three areas of the Philippines

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ABSTRACT

An assessment of the severity and extent of aquaculture impact and the estimation of sustainable carrying capacity were undertaken in three areas of the Philippines - Bolinao (marine site), Dagupan, (brackishwater) and Taal Lake (freshwater). This paper describes the potential mitigating measures that could be taken to reduce nutrient release from aquaculture, increase nutrient uptake using extractive species, and possible early warning systems for critical states of the tide when there is reduced flushing.

INTRODUCTION

Following the collection of data from the environmental surveys and production surveys, (Palerud et al., this issue) an assessment of the impact caused by the level of production in the three areas, estimation of the carrying capacity of the area and determinations whether the present production was above or below the carrying capacity where conducted (see Legović et al., this issue).

After an analysis of these data and from participatory workshops, a number of recommendations were drawn up to try and mitigate impact. These recommendations were, primarily, the reduction of nutrient output by improving food conversion rate, utilization of nutrients from fish production by extractive species such as oysters in marine and brackish water and hydroponics in freshwater, zoning of aquaculture into areas away from sensitive habitats and within carrying capacity of that zone, and farm management and planning solutions to reduce benthic impact. These recommendations are given in more detail below.

PLANNING AQUACULTURE WITHIN ZONES AND WITHIN CARRYING CAPACITY

Aquaculture production has environmental impacts, such as organic deposition and dissolved nutrients. These impacts are higher close to the farm. Thus, aquaculture zones should be located away from sensitive habitats such as coral reefs, seagrass beds, fish spawning areas, fry nursery areas, and mangroves. In Europe this distance has been determined at around 2 to 400 m (MEDVEG). Until further research on this has been undertaken in the Philippines, it is recommended that aquaculture zones are at least 300 m from sensitive habitats.

Significant impacts to benthic flora and fauna have been observed close to a fish farm. In Europe this distance has been found to be 25 m (MERAMED, http://meramed.akvaplan.com). To avoid this, cages should be placed in such a way that there is no significant impact on the environment outside of the aquaculture zone.

There should also be no significant impact outside the area of the farm or zone. Therefore, it is recommended that there should be a 20-m buffer between the cages and the edge of the zone. Moreover, a minimum distance of at least 20 m between large cages (i.e., more than 5 tons standing biomass) and 1 m between smaller cages, (i.e., less than 5 tons standing biomass, are recommended. Further, a 30-m distance between rows of cages is better.

When cages are placed close together, there are areas of continuous impact below the cages and if production is high, then there are continuous azoic areas, (see Fig. 1a).However, if the cages are spaced apart from each other, there are pockets of less impacted areas where benthic organisms can survive and thereby improve the ability of the sediment to assimilate the organic matter and recolonise the impacted areas (see Fig. 1b).

Depth of nets in cages

If there is insufficient distance between the bottom of the net and the seabed, the water flow becomes restricted below the net and the organic matter will build up directly below the net. In Europe, the recommended net depth is 1/3 of the water depth to allow sufficient water flow, provide oxygen, and allow sufficient dispersion of the organic sediments. It is therefore recommended that the depth of cage should be 1/3 of the total water depth.

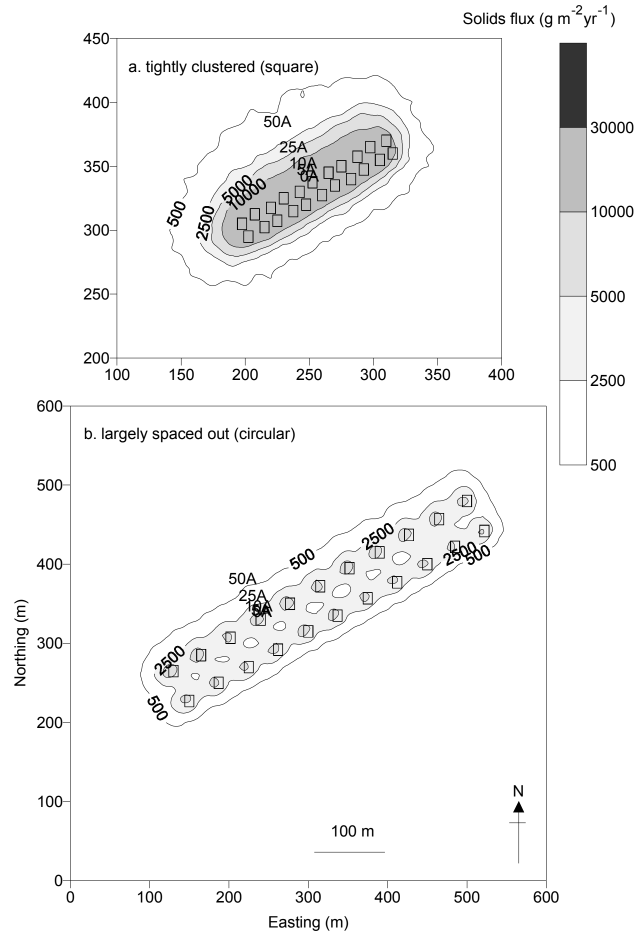

Figure 1. Model predictions of flux (g m^{-2} yr^{-1}) showing the significant difference in deposition footprint severity and extent when tightly clustered square cages (a) are replaced by circular cages spaced 30m (b). For the spaced-out cages, areas of lower flux are shown in between lines of cages which will tend to assist sediment processes (MERAMED, http://meramed.akvaplan.com).

FEEDING STRATEGY IMPROVEMENT

Feeds are the most important variable production cost. Food conversion rate in farms varies between 2.6:1 (milkfish) and 2.2:1 (tilapia) depending on the feeding strategy and close feed management. This overfeeding results in excess nutrients entering the aquatic ecosystem as organic sediments or dissolved nutrients in the water column. Minimizing waste from uneaten food will reduce the risk of environmental degradation. Reported waste loading rates per 1,000 kg of harvested shrimp have ranged widely, from 10 to 117 kg for N and 9 to 46 kg for P, depending upon FCR. For example, according to the Asian Shrimp Culture Council (1993a), the calculated waste loading rates per 1,000 kg of harvested shrimp would be as shown in Table 1.

By improving the food conversion rate from 2.5:1 to 2.0:1, the organic matter, nitrogen and phosphorus will be reduced by 30.0, 34., and 35.7% respectively.

Using modeling, the reduction of impact on the sediment can be demonstrated. Figure 2 shows that the area of high impact below cages can be reduced by reducing FCR from 2.0:1 to 1.6:1.

FCR	Organic matter (kg/ton)	Nitrogen (kg/ton)	Phosphorus (kg/ton)
1	500	26	13
1.5	875	56	21
2	1250	87	28
2.5	1625	117	38

Table 1. Kg per ton release of organic matter and nutrients with varying feed conversion ratio (FCR).

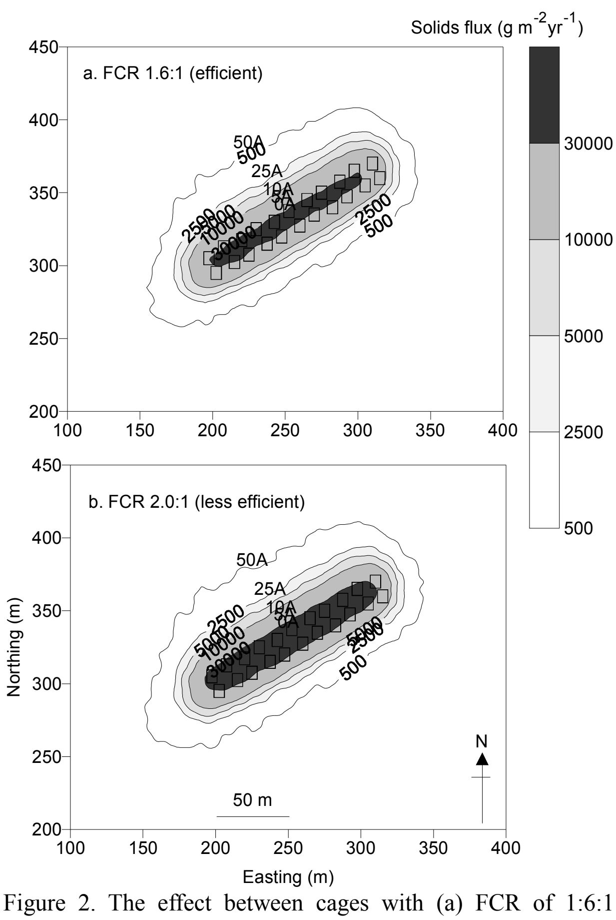

Figure 2. The effect between cages with (a) FCR of 1:6:1 (FI=111.6 kg cage) and (b) FCR of 2.0:1 (FI = 139.5 kg cage). A depth of 15m was used.

Methods to improve Food Conversion Ratio feedback systems

Traditional hand-feeding uses feed tables and the experienced eye of the operator to adjust the feed quantity to suit the needs of the stock. However, the operator tends to overfeed, especially in cages which have become larger and deeper, so that accurate visual observations of the stock have become more difficult. There is a relatively simple method of improving information feedback of feed consumption by means of a feeding tray (Fig. 3). A small feeding tray is made from split bamboo and mosquito mesh. This has a string long enough to reach the bottom of the cage. The tray could be fitted with a long bamboo to make the lifting easier. The tray is lowered to the bottom of the cage before feeding and then the operator starts to feed. After some time of feeding the tray is lifted out of the water to see if there are any pellets caught on the mesh. If there are pellets then feed would have been escaping from the bottom of the net without being eaten. If there are no pellets seen, then the tray is lowered again and feeding recommenced. This action is repeated until no pellets are found on the tray, at which time feeding is stopped for at least one hour.

Figure 3. Feeding tray with bamboo pole for ease of lifting.

A more sophisticated method is to use airlift pumps. Feed is given until a significant number of pellets are observed being drawn up through the airlift pump by the operators. Feeding is then stopped.

Reducing feed input

Another strategy to reduce feeding is to reduce the amount fed either by reducing daily ration or by not feeding on certain days.

A trial was undertaken on tilapia reducing feed intake at the Freshwater Aquaculture Center, Central Luzon State University. Results indicated that with feeding only 67% of the satiation ration, there was only slightly slower growth (Fig. 4).

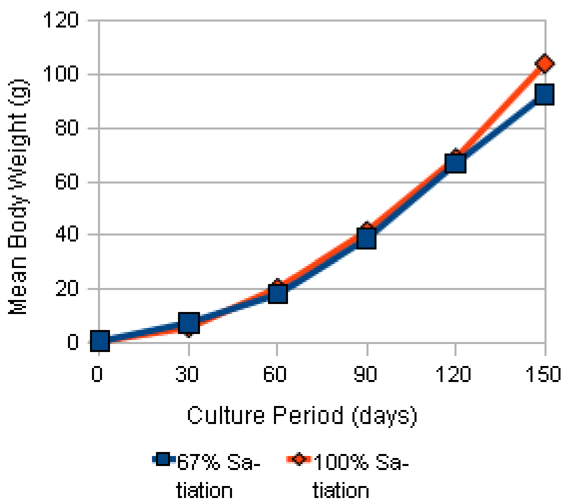

Figure 4. Change in growth rate with decreasing feeding level. (Source: Jimenez et al. 2006)

Performance	100% Satiation Level	67% Satiation Level
Mean final weight (g)	104.2 ± 37.1	91.7 ± 21.6
Mean daily weight gain (g/day)	0.69 ± 0.25	0.61 ± 0.14
Extrapolated gross yield (kg/ha)	3,196 ± 1,495	2,815 ± 1,098
Feed conversion efficiency	3.58 ± 1.22	2.73 ± 1.79
Survival (%)	79.7 ± 15	76.7 ± 16
Quantity of feed (kg/ha)	10,416 ± 3,642	7,094 ± 2,554

Table 2. Change in growth rate with decreased feeding level (Source: Jimenez, et al. 2006)

However food conversion rate was reduced significantly from 3.5: 1 to 2.7:1 (Table 2). This reduction would be the equivalent of not feeding the fish every third day.

INTEGRATED AQUACULTURE

Shellfish and finfish

One of the findings from the survey was that where there was a mix of fish and shellfish culture, the impact on the sediments was much less than when monoculture is being practiced. Therefore a recommendation is to encourage the mixing of fish and shellfish culture.

There are a number of culture methods that would be suitable depending on the depth of the water (see Figs. 5 and 6). Alternatives for positioning fish cages and mollusc culture are shown in Figure 7.

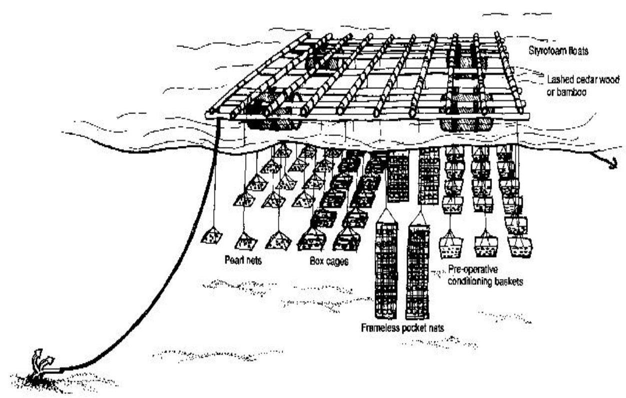

Figure 5. Alternative method for farming oysters on rafts in deep water. Raft pearl farm structure from Gervis & Sims 1992.

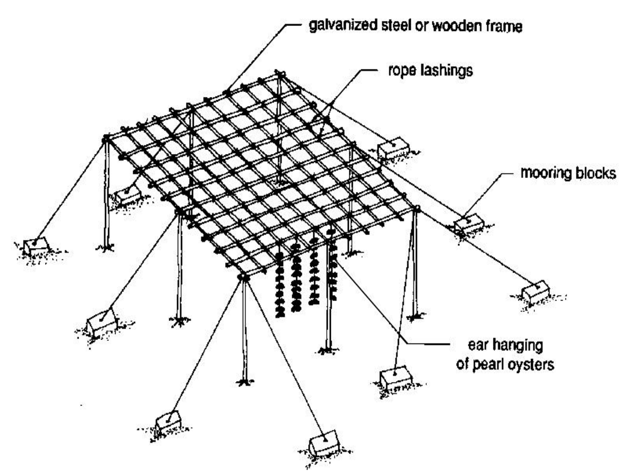

Figure 6. Farming oysters on trestles in shallow water. Trestle pearl farm structure from Gervis & Sims 1992.

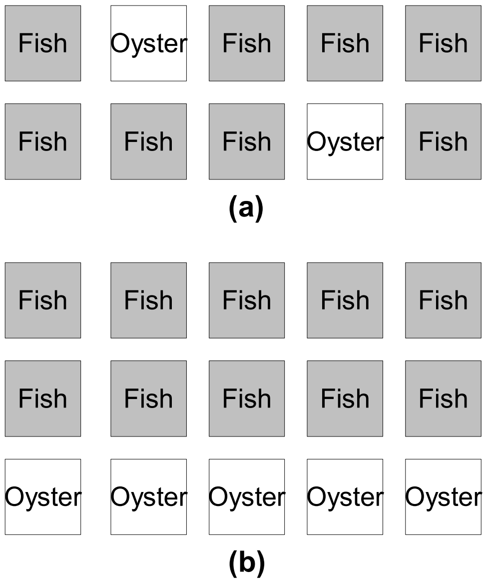

Figure 7. Ways of integrating shellfish and finfish: (a) Placing oyster culture alternatively with fish cage culture; (b) Placing oyster culture on the border of a fish cage culture zone.

Aquaponics

In freshwater there is the possibility to introduce hydroponics to extract nutrients. Hydroponic systems are designed to grow plant crops without soil and using only water to supply the nutrients. An aquaponic system is a symbiotic joining of aquaculture and hydroponics. Nitrogen waste from fish metabolites provides needed nutrients to the vegetable or plant crops. When plants remove these wastes, water quality is improved thereby encouraging faster growth rates and healthier fish.

In aquaponics, nutrient wastes produced by the fish are used to fertilize hydroponic floating production beds. This is good for the fish because plant roots and associated rhizosphere bacteria remove nutrients from the water. These nutrients - generated from fish waste algae, and decomposing fish feed - are contaminants that would otherwise build up to toxic levels in the water, but instead serve as liquid fertilizer to hydroponically grown plants. In turn, the hydroponic beds function as a biofilter so the water can then be recirculated back into the fish tanks.

Most plants can be grown in hydroponics (Fig. 8). This includes trees, shrubs, flowers, herbs, strawberries and most major crops. The most economical crops grown in Australia are lettuce, tomatoes, cucumbers, capsicums, strawberries, egg plants, and flowers such as carnations, roses, gypsophilia, chrysanthemums, and orchids, also a wide range of herbs are grown hydroponically.

Figure 8. Examples of floating bed aquaponics: (a) Rice plants cultivated on the surface of a fishpond; (b) Canna and umbrella sedge on floating beds; (c) Flowers; (d) Lettuce.

Figure 9. Coconut trees being grown in association with fish cages in Taal Lake.

Plants that will do well in any aquaponics system are any leafy lettuce, pak choi, spinach, arugula, basil, mint, watercress, chives, and most common house plants. In China, floating bed hydroponics have been developed for a number of plants and vegetables already. In the same manner, a primitive type of aquaponics was also being practiced in Taal lake using coconut tress (Fig. 9) and abandoned cages filled with grasses and floating water hyacinth.

EARLY WARNING SYSTEMS

In marine and brackishwater areas where currents are induced by tidal fluctuation, 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 10 shows such periods in the month of January 2005.

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

As tide tables are available on year in advance, it can be analyzed and a prediction made of the days with higher risks. Risk periods in Bolinao and Dagupan can then be identified as (Fig. 11):

- 22 and 23 March 2007
- 23 July
- 19 and 20 August
- 14 and 15 September
- 10, 11 and 26 October
- 5, 6 and 22 November
- 3, 4 and 19 December

If these dates are analyzed further critical times can be identified. This can be compared with the very low tidal difference occurring on 1st and 2nd June (Fig. 12). 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 analyzed in this way, an early warning calendar can be prepared in advance showing risk periods and critical risk periods.

CONCLUSIONS

A series of management measures are suggested to decrease environmental impact and increase present carrying capacity in three aquaculture areas of the Philippines. These measures include planning the spacing and depth of water below the cages, improving feeding strategies, integrating fish production with nutrient extractive species (integrated aquaculture), and consulting tide tables to identify periods when there is risk of low oxygens. Since these mitigation measures were drawn from case studies representing a lake, an estuary and a marine area, the same measures may be used in other other localities in the Philippines.

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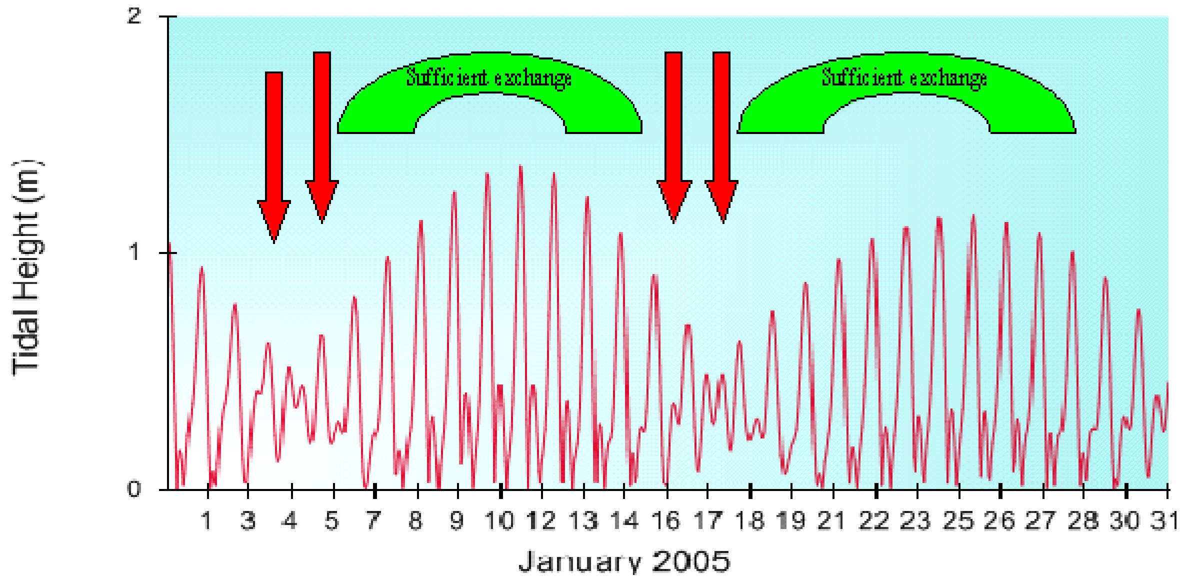

Figure 10. Periods during the month where there are sufficient exchange of water in the bay and periods when there are less exchange and greater risk (arrows).

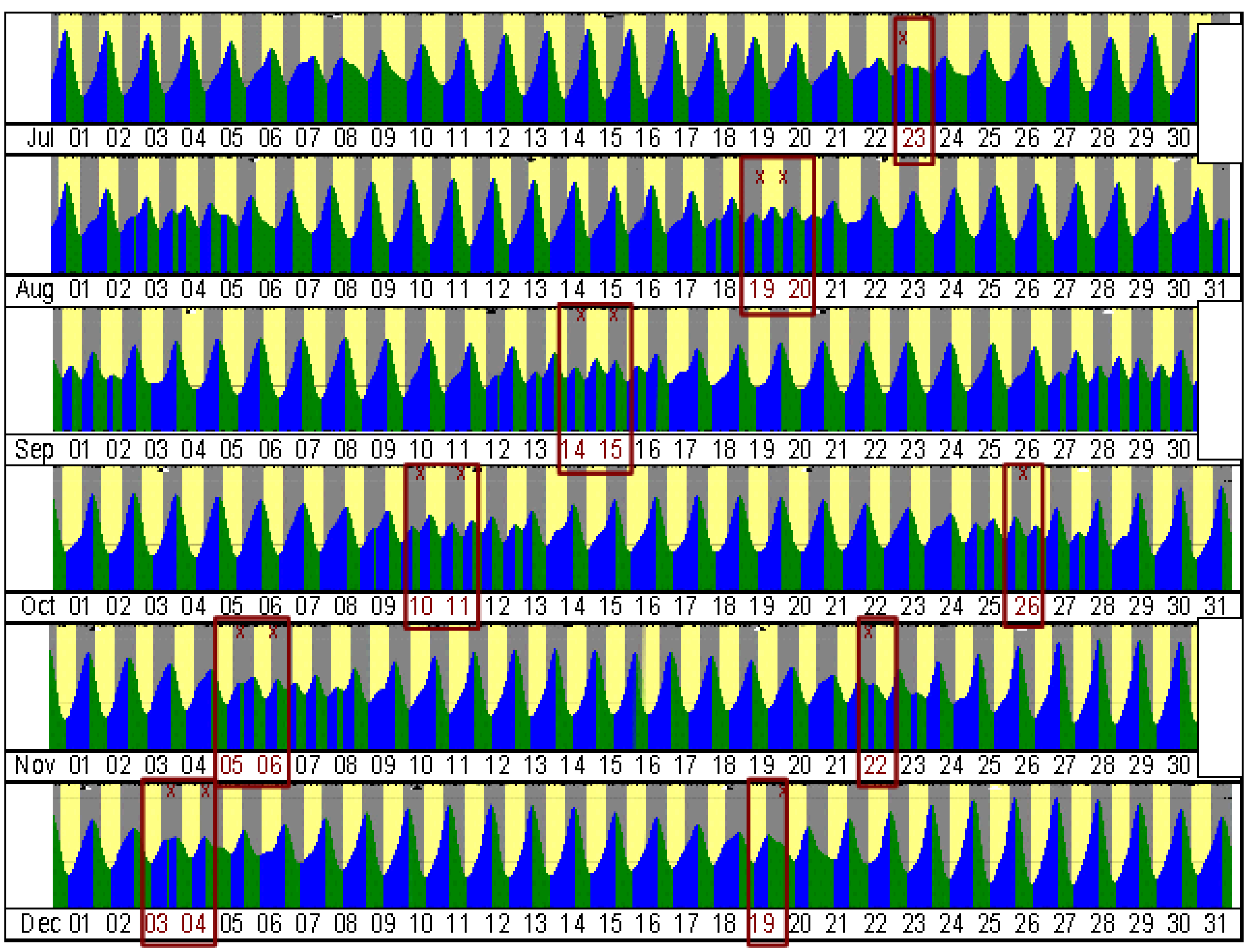

Figure 11. Bolinao & Dagupan: Tidal cycle through half the year of 2007 showing periods of highest risk (boxed).

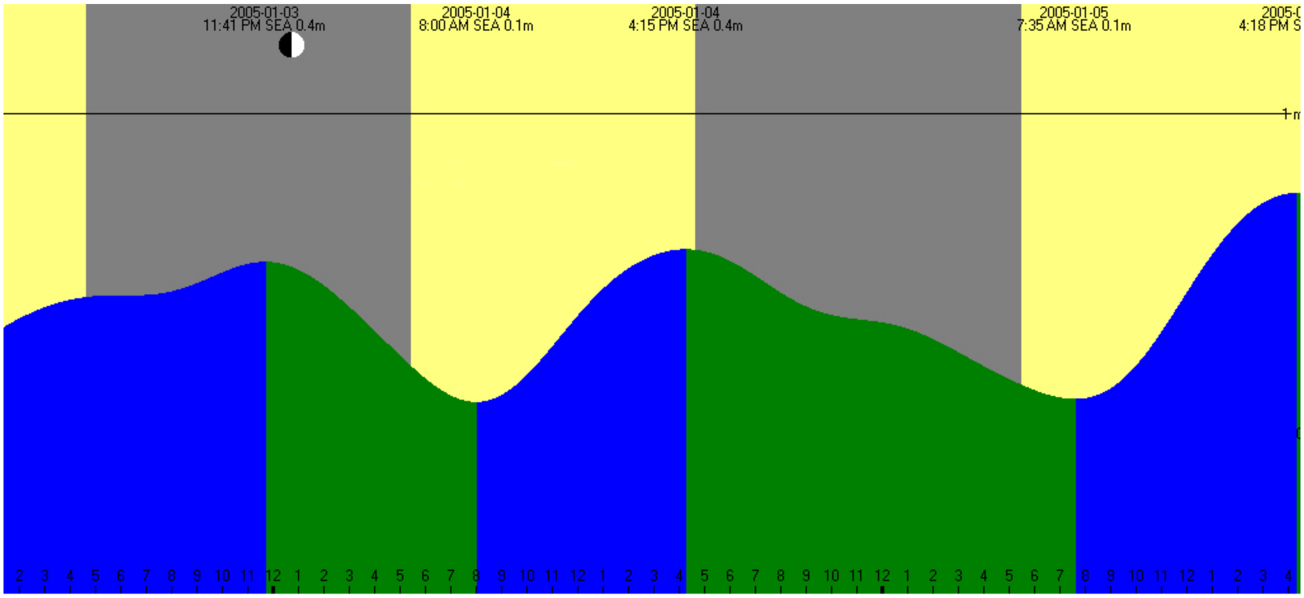

Figure 12. Tidal cycle on 1 and 2 June 2007.