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Bottom soil characteristics of brackishwater ponds after a culture period

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Abstract. Soil samples were obtained from two ponds used for the modified extensive culture of milkfish, *Chanos chanos* and three semi-intensive shrimp, *Penaeus monodon* ponds immediately after harvest. The ponds were used as experimental ponds that are located at a research institute in Central Philippines, and with a culture period of four months for both systems. Soil pH, potential acidity, available phosphorus and organic matter content were determined from the soil samples. The ponds from both culture systems had soil pH ranging from slightly acidic to slightly basic. The potential acidity in milkfish ponds ranged 18.4–28.97 meq H^+ per 100 g of soil, while it ranged 14.7–21.42 meq H^+ per 100 g of soil in the shrimp ponds. Available phosphorus was more or less similar in both culture systems. The mean organic matter content (%) in milkfish ponds was 2.62$\pm$0.4, while that in shrimp ponds was 1.90$\pm$0.6. These results are crucial in subsequent pond preparation activities because the levels of these different chemical parameters would determine the amount of inputs that are needed in the pond prior to the actual culture. Appropriate amounts of inputs, whether organic or inorganic, that are added during the pond preparation stage will significantly affect the pond performance during the culture period.
Key Words: bottom soils, chemical composition, brackishwater ponds, aquaculture.

Introduction. The nature of a particular soil type is dependent on its physical properties and nutrient content (George et al 2010). Soil quality is an important factor in fish pond productivity as it controls pond bottom stability, pH and salinity. It also regulates the quality of the overlying water (Hill 1976; Ekubo & Abowei 2011). In general, moderately heavy textured soil having moderate organic matter content is desirable for aquaculture (Welch et al 1977). The fish pond soil is made up of sediments, which are composed mainly of loose sand, silt and other soil particles that settle at the bottom (USEPA 2002). They can come from soil erosion or from the decomposition of plants and animals. Sediments also serve as an important habitat for the benthic macro-invertebrates whose metabolic activities contribute to aquatic productivity (Abowei & Sikoki 2005). Important macronutrients such as nitrogen and phosphorous are continuously being interchanged between sediment and the overlying water (Abowei & Sikoki 2005).

The most important function of the pond soil is for the retention of water. It is used as substrate and for the construction of dikes. The quality of the soil is a crucial factor in determining the productivity of the fish in the ponds. Soil controls pond bottom stability, pH and salinity. The suitability of sites for pond culture of aquatic organisms requires good soil characteristics. As such there is the need for a good soil background for proper decision on a site for carrying out pond culture activities (Hubert et al 1996).

In the Philippines, the culture of fish and shrimps in ponds comprises a significant bulk of the aquaculture industry. Among the aquatic species used for aquaculture, milkfish, *Chanos chanos* and shrimp, *Penaeus monodon* are the preferred species for pond culture because of their high demand both in the domestic and international markets. Several pond culture activities for both species have been practiced, each requiring varying levels of inputs before and during the culture operations. The inputs that are not utilized during the culture period as well as excess natural productivity usually end up at the pond bottom. These in turn affect the characteristics of the pond bottom after harvest. The chemical composition of the pond bottom will have a significant effect on subsequent culture activities as this provides information on the level of inputs required during the pond preparation activities (Ekubo & Abowei 2011). Hence, in the present study the chemical composition of the bottom soils in ponds used in the modified extensive culture of milkfish and semi-intensive culture of shrimps was determined. The results will be used as information on future management of aquaculture activities in the ponds using these aquatic species at different levels of culture.

Material and Method

Sampling site. The study was conducted at the Brackishwater Aquaculture Center, University of the Philippines Visayas. Soil samples were obtained immediately after harvest from two ponds that were utilized for the modified-extensive method of culturing milkfish, *Chanos chanos* and three earthen ponds that were used for the semi-intensive culture of shrimps, *Penaeus monodon*. These ponds served as experimental ponds at the research center and have been continuously used for more than twenty years. The culture period for both systems was four months (January to April during a culture operation in 2005).

Sampling of bottom soils. Soil samples from each pond were taken within a day after the harvest of the cultured stock. Sampling procedures were done following the recommended guidelines of Ritvo et al (1998) to avoid biases in chemical analyses. The soil samples were placed in plastic buckets and transported to the laboratory where they were air-dried for 2-3 weeks. After air-drying, the samples were ground, sieved through a 2 mm mesh stainless steel screen and a composite sample of 1 kg was obtained. Individual composite samples were kept in plastic bags for subsequent chemical analyses.

Chemical analyses. The soil samples were analyzed of selected chemical properties. Soil pH was taken using a pH probe. Potential acidity, expressed as meq H^+ acidity per 100 g of soil, was determined by the titrimetric method using sodium hydroxide after the oxidation of hydrogen peroxide in the soil samples (Konsten et al 1988). Organic matter (%) was measured by digestion of the soil samples with dichromate solution following the procedures described by Walkley & Black (1934). Available phosphorus content (mg per liter, ppm) was analyzed using the procedures of Olsen et al (1954). The percentages of carbon (C) and nitrogen (N) in the soil were derived from the values obtained in the determination of organic matter content.

Results and Discussion. The soil samples in the present study were obtained after harvest from brackishwater ponds used in the modified extensive culture of milkfish and semi-intensive culture of shrimp. After harvest, the bottom soils in ponds used for milkfish culture had a pH values in the range of 6.8-7.05, which was slightly acidic to neutral pH. The potential acidity was at 23.72$\pm$5.6 meq H^+ acidity per 100 g of soil. Available phosphorus was in the range of 34.78–10.86 ppm, with an average of 17.8$\pm$9.1 ppm. The mean organic matter content (%) was 2.62$\pm$0.4, and the derived average values for the carbon (%) and nitrogen (%) content was 1.52$\pm$0.23 and 0.13$\pm$0.02, respectively. Table 1 shows the profile of the chemical composition of the bottom soils from the modified extensive milkfish ponds.

The chemical composition of the bottom soils obtained from semi-intensive shrimp ponds after harvest is shown in Table 2. The mean pH of the soil from semi-intensive shrimp ponds was 7.1$\pm$0.18. Potential acidity ranged 14.7–21.42 meq H^+ per 100 g of soil. The mean available phosphorus content is 16.4$\pm$4.1 ppm. Organic matter content ranged 1.3–2.74 ppm and the corresponding average values for carbon (%) and nitrogen (%) contents were 1.10$\pm$0.34 and 0.17$\pm$0.23, respectively.

Table 1
Chemical compositon of the soil immediately after harvest from brackishwater ponds used in the modified extensive culture of milkfish, *Chanos chanos*

Parameter	*Mean ± S.D.*	*Range*
pH	6.9 ± 0.09	6.8 + 7.05
Potential acidity (meqH$^+$/100 g soil)	23.72 ± 5.6	18.4 – 28.97
Available phosphorus (ppm)	17.8 ± 9.1	10.86 – 34.78
Organic matter content (%)	2.62 ± 0.4	2.2 – 3.0
Carbon content (%)	1.52 ± 0.23	1.28 – 1.74
Nitrogen content (%)	0.13 ± 0.02	0.11 – 0.15

Table 2
Chemical compositon of the soil immediately after harvest from brackishwater ponds used in the semi-intensive culture of shrimp, *Penaeus monodon*

Parameter	*Mean ± S.D.*	*Range*
pH	7.1 ± 0.18	6.7 + 7.20
Potential acidity (meqH$^+$/100 g soil)	17.35 ± 2.4	14.7 – 21.42
Available phosphorus (ppm)	16.4 ± 4.1	11.08 – 22.88
Organic matter content (%)	1.90 ± 0.6	1.3 – 2.74
Carbon content (%)	1.10 ± 0.34	0.76 – 1.60
Nitrogen content (%)	0.17 ± 0.23	0.07 – 0.13

In the present study, we analyzed selected chemical properties of bottom soils obtained from both ponds used for modified extensive rearing of milkfish and semi-intensive culture of shrimps immediately harvest. There were slight differences between the two levels of culture system, however, no statistical comparison was made because two different species were used. Hence, it was deemed necessary to just present a profile of the levels in the chemical composition of the bottom soils in order to provide information on the corresponding management procedures in pond soil management after each cropping period.

In the pond culture of milkfish, the stock usually relies on the presence of natural food mostly during the first two months and ocassional feeding could be done when the growth of natural food becomes scarce towards harvest (Kühlmann et al 2009). The natural food is mainly composed of greenish algal mats associated with unicellular organisms and crustaceans (Kado et al 1989; Fortes & Pinosa 2007). If the stocking density is low, regular application of inorganic fertilizer is done to maintain luxuriant growth of the natural food (Jaspe & Caipang 2011). The growth of natural food in the ponds is enhanced by the addition of lime and fertilizers during preparation (Otubusin & Lim 1985), and obtaining the chemical composition of the soil during pond preparation or immediately after harvest is important as this could aid in calculating the amount of inputs to be added into the ponds.

On the other hand, in semi-intensive shrimp ponds, there are more inputs into the system as a consequence of higher stocking density. Although, the term semi-intensive as used in shrimp aquaculture varies by definition according to some authors (Deb 1998; Primavera 1998), this system relies mostly on the use of hatchery-produced seedstock, application of lime and fertilizers and the provision of supplemental feed (Shahidul Islam et al 2004). These inputs together with waste materials of the cultured stock and uneated feeds make up the organic matter substances that are deposited in the ponds after harvest.

Pond sediments are dependent on the kind of soil where the pond is located and how the pond was utilized (Shahidul Islam et al 2004), however, it was observed that the bulk of sediments in shrimp ponds are composed mainly of clay materials (Smith 1996), which were also apparently found in the study. It was also shown that shrimp ponds have usually high loads suspended solids and high densities of phytoplankton (Jones et al 2001). High amounts of inorganic nutrients coupled with high phytoplankton density are indicators of a productive pond environment, and the presence of significant amounts of bacteria could result in the active mineralization of the pond effluent (Trott & Alongi 2000). The levels of organic matter in both milkfish and shrimp ponds after harvest were moderate based on the scale proposed by Welch et al (1977) and deemed to be favorable for pond culture. These conditions suggest the possibility of biomineralization of these substances, which in turn are converted into nutrients for natural production or are eventually flushed out during regular water exchange. These conditions were also reflected by the moderate amounts of nutrients including nitrogen and available phosphorus, that are required for natural productivity.

Nitrogen and available phosphorus are primary nutrients in both fish and shrimp ponds. Organic matter supplies the bulk of nitrogen present in the soil. This nutrient undergoes many transformation and reactions in the pond soil, including nitrogen fixation, denitrification and nitrification, which are controlled by soil organisms. On the other hand, phosphorus is an important nutrient in ponds because its deficiency inhibits the growth of phytoplankton. Monitoring of the available phosphorus is necessary because this is the component that is directly utilized during the production of natural food. If the soil pH is lower than 5.5, phosphorus is adsorbed on clays and humus particles by forming chemical bonds enabling its fixation and thus not available to the phytoplankton in the pond. Available phosphorus is that portion of the soil phosphorus readily absorbed by phytoplankton and other organisms (RPI 1985). Both of these are directly related to the amount of organic matter in the bottom soils, thus, these two nutrients were more or less similar in both pond culture systems in the present study.

Some common soil problems that can hinder fish cultivation are acidity, alkalinity and excess organic matter (Dance & Hynes 1980). The major source of acidity in soils is due to the oxidation of sulfides resulting in the formation of acid sulfate soils. Acid sulfate soils are usually present in low lying coastal areas where sulfides are being accumulated in marine sediments as a result of bacterial reduction of seawater sulfates. In ponds that are constructed in mangrove swamps, the formation of acid sulfate soils is common because of the abundant supply of sulfates and organic matter. In this study, the ponds used for both milkfish and shrimp culture are located in a low lying coastal area and used to be mangrove swamps. However, these ponds have been used for more than 20 years, thus, the problem of acid sulfate soils is prevented. This is shown by the almost neutral to slightly alkaline conditions of the bottom soil of the ponds after harvest. The favorable pH of the pond soil has an effect on productivity in the subsequent culture operations and at the same time will determine the amount of inputs such as lime and fertilizers that need to be placed in the ponds during preparation.

Conclusions. In summary, the chemical characteristics of the bottom soils of ponds from a modified extensive system used for the culture of milkfish and from semi-intensive culture of shrimp were measured. The levels of the parameters that were measured did not widely vary although slight variations were observed. The observed similarities in the chemical characteristics in the pond soils of both culture systems could be brought about by the stability of the chemical composition over time and may not be significantly affecte by the level of intensity in culture. However, thorough monitoring of the chemical characteristics of the pond soils must be strictly observed because adequate knowledge on the pond soils is necessary for effective culture management and practices.

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