Coastal environment and human activity in the Philippines

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Our component has been conducting comprehensive environmental studies in four coastal areas with different environmental and social conditions namely, Batan Bay Estuary (Philippines), Rayong Bay and Bandon Bay (Thailand), and Hue Bay (Vietnam). The main goal is to describe patterns of material flows in these areas with the specific objectives to investigate the following: (1) water and bottom conditions; (2) marine food-web structures; (3) water circulation patterns using ICP-MS data; (4) land utilization profiles, (5) chemical pollution; and (6) productivity of mangrove areas. Interactions of these environmental factors to human activities will be correlated and discussed. Expected outputs at the final fiscal year of the project will be two books collaborating with C2 and other components. One is a part of the series book written for Japanese citizens. The other one will be written in English and for scientists interested in trans-disciplinary environmental research in coastal areas of Southeast Asia.

In Batan Bay Estuary, the specific research objectives are the following: (1) preparation of a land utilization map by GIS; (2) determination of the origins of water and minerals by ICP-MS & Sr in water and sediments; (3) estimation of mangrove production; (4) determination of iso-scape in mangrove areas; (5) estimation of litter production by mangrove forests; (6) assessment of material flows in the sea (food-web structure); (7) investigation on the role of microhabitats as shrimp nursery; (8) assessment of mangrove rehabilitation on benthic faunal community (9) assessment of chemical pollution (heavy metals, agricultural chemicals, etc.); (10) determination of water and bottom conditions including AVS levels; and (11) assessment of temporal changes in hydrographic conditions.

The activities (both completed and upcoming) and preliminary results are as follows:

(1) A GIS map showing land-use profile is currently being finalized. **(2)** To understand the current physico-chemical state and the key factors that contribute to water quality, spatial variations in elemental and isotopic Sr compositions were determined in water samples collected from 36 sites surrounding the bay area. In general, dissolved concentrations of the elements of concern in coastal waters (e.g. Pb, Cd, Ni, Sn, Cu) were within the current regulatory limits set by the Department of Environment and Natural Resources (DENR) of the Philippines. The spatial distribution of Sr isotope ratios ($^{87}Sr/^{86}Sr$) suggests that the estuary water is mostly ocean influenced ($^{87}Sr/^{86}Sr \approx 0.70916$; Sr concentration 51.40-80.87 μmole/l). However, a number of stations within the estuary exhibited very different $^{87}Sr/^{86}Sr$, suggesting possible anthropogenic influences in the local scale. Inland water bodies including river tributaries of the bay generally exhibited lower Sr concentration (0.71-5.50 μmole/l) and $^{87}Sr/^{86}Sr$ ratios (0.707-0.708), which correlates well with the lower salinity levels (0-2.3 ppt).

[(3) (4) (5)] To clarify the contribution of mangrove plants as a producer in the ecosystem, $\delta^{13}C$ was measured for 202 mangrove plants and for surface sediment organic matter collected at 157 points. Sampling was conducted from June 2012 to September 2013 (just before Typhoon Haiyan). The $\delta^{13}C$ of mangrove plants varied from -31.6 to -27.9‰ reflecting that all of mangrove plants were C_3 plants. Back mangrove plants tend to showed higher $\delta^{13}C$ reflecting higher osmotic stress for these plants comparing to true mangrove plants which evolutionally developed mechanisms against salinity. As $\delta^{13}C$ of mangrove plants (-30.3±1.6‰) was far lower than $\delta^{13}C$ of phytoplankton (-25.2±1.6‰), the relative contribution of mangrove origin organic matter could be estimated by determining $\delta^{13}C$. Samples from the rivers connected to the bay and the inner part of the bay showed lower $\delta^{13}C$ reflecting the importance of terrestrial and mangrove origin organic matter in these points. Microspatial scale variation of $\delta^{13}C$ of sediment organic matter also observed along the gradient from remnant mangrove stands (-27.5‰) to open water (-24.8‰) located within a hundred m distance. As a conclusion, the spatial pattern of sediment $\delta^{13}C$ in the bay well explained by the distribution of mangrove forest and two entrances of the bay in 1953, even the most of the mangrove was lost during the 1990s and one of two entrances was closed 20 years ago. It suggests that the long lifespan of sediment organic matter and the relative stability of sediment in the bay.

(6) To grasp the food web structure of marine products and relationship with the characteristics of fishing gears in small scale, marine products were collected at 7 sites by different fishing gears in March and June 2014. In total, 1,181 individuals (include formalin samples and same species in different sites) in 7 sites in March; and 2,036 individuals in 7 sites in June have been collected for CN isotope analysis. Food web structures from $\delta^{13}C$ and $\delta^{15}N$ will be examined through seasonal and spatial differences including features of various fishing gears.

(7) To assess role of abandoned ponds as shrimp nursery areas, shrimp and fish assemblage structure with different ages and conditions were surveyed at 8 sampling stations (established during the initial sampling in Sep 2013) and at 2 additional stations during the second to forth sampling in March, September 2014 and March 2015. Small shrimp and fish were collected by towing a small seine net in the middle tide during the daytime, 3 times over 10 m tow at each station over the bare substrate in ponds and fringe of mangroves, or over vegetation at a seagrass station. The results (exclude March 2015; detail analysis was not yet finished) suggest that fish diversity decreased with culture pond constructions but abandoned ponds still provide habitat for particular shrimp and fish species. Density of fish and shrimps were not clearly different between abandoned ponds with bare substrate and mangroves. Samples taken in March 2014 (after the super typhoon in 2013) showed reduced diversity and abundance of shrimp and fish for most stations, implying an impact of the natural disaster. However, detail result of 2015 March sample would allow clearer conclusion. Stable isotope and gut contents will also be analyzed for further discussion.

(8) The impacts of mangrove rehabilitation on benthic faunal community in Batan Bay, Panay Island, Philippines, were investigated by assessing both numerical and functional response of community structures. The benthic invertebrates were collected from 5 replicate quadrats (20×20 cm) by excavating the soil to a depth of 20 cm in natural mangrove areas, rehabilitated areas, and abandoned fishponds in October 2014 and April/May 2015. The soil was sieved through 1 mm mesh, and the residue was preserved. Benthic organisms were later sorted from the soil, identified to the most possible taxonomic level, counted, and wet weighed. In addition, the carbon and nitrogen stable isotope ratios of the samples were estimated by using an IRMS (Thermo Fisher Scientific Co. Ltd.). Results show that the abundance and biomass are not significantly different among natural mangrove areas, rehabilitated areas, and abandoned fishponds. However, species

richness was highest in natural mangrove areas. The carbon and nitrogen stable isotope ratios indicated that food chain length of natural and rehabilitated mangrove areas were longer than that of abandoned fishponds. Overall, mangrove rehabilitation could easily recover functionality of the benthic faunal community but not numerically.

(9) To ascertain the degree of metal contamination in water, sediments, finfishes and shellfishes, 51 water samples, 32 sediment samples and 27 finfishes were collected in June 2012. Shellfishes (9, 4 and 7 species of crustaceans, gastropods and bivalves, respectively) were also collected in October 2013. Samples were processed and measured for heavy metals using ICP-MS for water and FAAS for sediments and fishes. Metal concentrations in sediments ranged from ND – 1.38 μg/g for Cd; 16.57 – 143.02 μg/g for Cu and 3.18 – 28.53 μg/g for Pb. Generally, finfishes are safe for human consumption based on their heavy metals (Cd, Cu and Pb) contents. Twelve samples consisting of 4 crustaceans, 4 gastropods and 4 bivalves have Cd concentrations higher than the FAO/WHO standard (5 μg/100 g). Among the shellfish samples, only gastropods exhibited Pb concentrations beyond the standard of 150 μg/100 g. These gastropods species also accumulated Cu metal and exhibited 2 – 14x greater than the standard (1000 μg/100 g). Most of the shellfishes are good accumulators of Cd, Cu or Pb or combinations of these metals and are generally unsafe for human consumption based on the FAO/WHO standards. In addition, to clarify the pollution status by spilled oil in Cebu, Philippines on August 16, 2013, we collected coastal sediments at Cordova, Cebu, Philippines on August 19, 2014 and August 28, 2015. We analyzed polyaromatic hydrocarbons (PAHs), alkylated PAHs and hydroxylated PAHs due to their toxicity on aquatic organisms. Total PAH concentration in St.1 was 4.88 mg/kg dry weight and each PAH also showed the highest concentration. On the other hand, total alkPAH concentration in St.2 was 6.07 mg/kg dw and each alkPAH showed the highest concentration except for alkylated naphthalenes. The diagnostic ratios suggest that source of oil pollution in St.1 and 2 were petrogenic but not in St.3. Hydroxylated PAHs as metabolites of PAHs were detected in all stations and seawater. These results suggest that the sampling sites in Cordova were still polluted by spilled oil even 1 year after oil spill.

(10) The sediment acid volatile sulfide (AVS) concentrations were measured for samples collected at 0-1 cm, 1-2 cm, 5-6 cm from the sediment-water interface for two sampling periods (February and June 2013). Sediment mean AVS ranged from 0 to 0.6601 mg S/g dry sediment in February 2013 and a relatively higher range of 0.183 to 1.198 mg S/g dry sediment in June 2013. It was noted that the critical level of (AVS >0.2 mg/g) were mostly monitored in fishpond sediments in contrast to the lower AVS found in river sediments. Sediment mean organic matter ranged from 3.5 to 24.6% dw with higher level of OM found upstream of rivers and areas with mangrove and a strong correlation was observed between AVS and OM ($r^2>0.9$). On the other hand, dissolved oxygen in water (near the sediment-water interface) ranged from 1.9 to 9.9 mg/L. Most sites have DO concentration below optimum level for fish (4 mg/L) especially near ports and mangroves while some areas with DO level higher than 4 mg/L were monitored in the mouth and middle of rivers. This result conforms to the observations that higher AVS concentrations are associated with organically rich and anoxic sediments and lower concentrations are found in oxic sediments with lower organic matter.

(11) Together with local counterparts from CFMS-ASU, nutrient levels (P, N, etc…) and plankton composition and abundance were determined from March to July 2014. Results are currently being processed and proposal is being prepared for the CFMS-ASU to conduct independently the second set of field and laboratory activities.

Finally, the destruction of mangrove, abandonment of shrimp ponds, overfishing, and stock enhancement of tiger prawn are considered to be human activities that have substantial impacts on natural environments on Batan Bay Estuary.