COMPLIMENTARITY OF SENSOR-BASED MEASUREMENTS AND COMMUNITY PERCEPTION FOR MONITORING AND MANAGEMENT OF SEAWATER QUALITY

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Abstract: Puerto Galera, endowed with rich and diverse marine resources, is a popular tourist spot in the Philippines. However, its bays are vulnerable to gradual seawater quality degradation. The aims of this research are to relate the impact of human activities in some tourism areas to seawater quality and to show that integrated socio-environmental approach can emphasize the community's role in water quality improvement efforts. The socio-environmental monitoring was performed in three tourism sites in Puerto Galera, namely: Muelle, White Beach and Sabang to assess the impact of human activities to seawater quality. Physical monitoring includes water quality measurements by vertical profiling STD-type sensors along the shorelines of these sites. Social monitoring includes information of the behavior, perception and level of environmental awareness of the community obtained through interview surveys. Comparison revealed positive agreement between the community's perception on water quality and those of the sensor-based measurements. The resulting correlation also reflects different level of environmental awareness among communities. Further, results indicate that communities may have the inherent capacity to perform water quality monitoring. Communities with the highest level of awareness possess improved sanitation practices and hence good seawater quality.

Key Words: socio-physical survey, Puerto Galera, tourism, water quality, perception, remote sensing, GIS

1. INTRODUCTION

Aside from being a source of food and livelihood for the people, the diversity and richness of coastal and marine resources of the Philippines offer scenic and recreational attraction for the tourists and consequently generate income for the tourism-oriented businesses. Demands of growing population and influx of visitors in the recent years have compelled citizens to resort in unregulated development activities (Fortes, 1997). However, this type of development poses degradation to the environment, among which, water pollution brought about by improper sewage and wastewater discharges ranks one of the highest threats. Maintenance of a high level of water quality is essential to sustain pleasant and healthy environment but at the same time requires proper management based on thorough

understanding and continuous monitoring of both the seawater quality and the existing community sewage and wastewater conditions.

In Puerto Galera, Oriental Mindoro (see Figure 1), the people and its local government have relied mostly on occasional water quality analysis performed by academic researchers and by national government agencies. Most of the time, the results of analysis were not fed back directly to the municipality. Therefore, some research results on water quality and their respective recommendations fail to appeal the local people due to (i) lack of trust by local resident on researchers most of whom do not hail from Puerto Galera; (ii) ineffective dissemination to the local people because results are presented in a form or language not easily understandable; (iii) unclear link between the water quality and local people's activities. Moreover, the physical conditions at which the tourism sites in Puerto Galera are exposed vary from one site to another. Therefore, efforts to mitigate water quality deterioration depend on local people's cooperation and their understanding of the processes involved. Hydrodynamic simulation of Puerto Galera revealed that seawater of low quality may accumulate in some bays and showed that the opening of a sand bar proposed by some residents as a possible solution to the pollution problem posed minimal improvement on the overall water quality condition. Thus, seawater quality improvement would require integrated socio-physical analysis approach.

Figure 2. Location map of Puerto Galera (left, within rectangle)
Satellite image (right) showing its major villages.

The aims of this research are to relate the impact of human activities in some tourism areas of Puerto Galera to seawater quality and to show that integrated socio-physical approach to water quality can strengthen the local people's role in water quality improvement efforts.

2. METHODOLOGY

2.1 Study area: Tourism area clustering for comparison

There are 13 villages (12 of which are coastal) in Puerto Galera. Half of the coastal villages rely on tourism-based activities for sustenance (Cola and Hapitan, 2004). For this research, the focus will be limited on the specific clusters of tourism-related establishments and household communities situated along the coastline. The basic assumption is that those communities closest to the bay pose greater impact to seawater quality and posses better knowledge on water quality conditions. The major tourism-related clusters considered in this research are Muelle, Sabang and White Beach. Social data used to describe these clusters are referred from their encompassing villages (*barangays*). Characteristics common to these three clusters (Book of Puerto Galera Facts, 2002) include (1) ferry arrival points for tourist (but only Muelle has pier structure); (2) high concentration of hotel and restaurant establishments; (3) highly-dense communities and; (4) rapid population growth.

2.1.1 Muelle (covered by Barangays Poblacion and Sto. Niño)

Muelle is the busiest and oldest of the three ports in Puerto Galera. Situated within a natural harbor, its still bay water serves as haven to more than 20 moored yachts and is the preferred take-off point to other popular tourist destinations. Sto. Niño absorbs the expansion of the town center with commercial establishments such as small eateries, T-shirt and garment shops, groceries, restaurants and lodging facilities lining up along the port catering to tourists' daily needs. Its annual population growth rate, 6.41% is highest among the villages against 2.3% and 2.4% municipal and national growth rates respectively.

Muelle Bay experiences the less anthropogenic influence over water quality but due to its physio-environmental characteristics, its carrying capacity for wastewater is quite low. Seawater in Muelle is highly turbid, mainly because of its enclosed bay form resulting in very poor water exchange with the open sea and is a port area. Nutrient loads come from small freshwater creeks discharges during the rainy season and from direct inputs of wastewater and sewage (San Diego-McGlone et al., 1995). There is no sewerage system and sewage effluents are normally discharged in open canals leading to natural waterways, like rivers and streams eventually ending up to the bay (Bio-social survey of the coastal waters of Puerto Galera, Mindoro Oriental, 1984).

2.1.2 Sabang

Sabang, where most of the upper-class hotels and better restaurants in Puerto Galera are found, is a favored destination by some tourists for its active nightlife and scuba-diving facilities. Numerous diving centers, hotels, restaurants, discos, nightclubs and versatile shops lie along its shoreline further reducing what is already a narrow beach (submerged during high tide). Establishments are mainly managed by foreigner-Filipino couples. Nearshore seawater in Sabang already shows symptoms of eutrophication and algal bloom. Untreated wastewater discharges from commercial establishments and households that directly drain to beach waters through open canal and over the beach sand are evident.

2.1.3 White Beach (in San Isidro village)

White Beach may be considered as the "budget" version of Sabang and has been mostly patronized by local (Filipino) tourists. It has a long and extensive beach that stretches up to 30m in width and 800m in length and is preferred for beach-combing, swimming, beach volleyball, disco, massage, drinking and camping activities. The establishments here are managed mostly by local residents. There are more than 30 hotels and lodging facilities in this area. As compared to the previous two sites, White Beach has relatively the cleanest water due to better wastewater facilities and effluent discharge practices. It has well-constructed canal system for wastewater leading to a natural retention pond.

2.2 Data Gathering and Sources

A combination of social surveys and technology-based approach form the data gathering strategy. Social surveys include inventory of households, tourists' infrastructure and water sanitation facilities. Questionnaires were also distributed and interviews were conducted to gather community perception. Remotely-sensed data was used to map out the land cover while a hand-held global positioning system (GPS) was used to establish location of

tourism establishments. All of these data were organized via a Geographic Information Systems (GIS).

2.2.1 Questionnaire + interview survey for tourism and household sectors

A structured questionnaire with interview was used as a socio-environmental survey tool. The purpose of questionnaire survey is to determine the local people's activities and their perception of seawater quality in the three tourism areas of Puerto Galera. The survey was conducted on the first week of March 2006. The survey was divided into two main parts: behavior/activities related to water quality and perception to seawater quality. The first part includes questions related to availability of sanitation facilities and local peoples' sanitation practices. Two sectors of the community were considered, namely:

1) *Households*, which were represented by heads of the families. In most areas, except in Muelle, respondents were only taken four-household intervals due to large number of households. This sector was mostly located behind those of tourism-related business establishments (301 respondent-households).
2) *Tourism establishments*, which were represented by either the hotel/resort/restaurant owners or managers. The presence of establishments in areas closest to the shore was presumed to be directly related to their desire to have contact with tourists (66 respondent-tourism establishments).

The division of respondents is necessary for differentiating the influences and perceptions on seawater quality between that of households (may or may not be involved in tourism) and tourism (directly involved in tourism) sectors. The questions were written in English for tourism sector and in Tagalog for the household sector.

2.3 Availability of sanitation facilities

Poor sanitation facilities are considered one of the main reasons for increased nutrient loading on the bodies of water. Survey questions pertain to existing sanitation and waste disposal facilities in each tourism area. The types of toilet and septic tank were particularly asked since it indicates socio-economic status of the people using it.

2.4 Local peoples' sanitation practices

This part of the questionnaire focuses on how individuals may have contributed to water quality deterioration. The respondents were asked where they dispose their wastewater and what activities do they engage in involving the use of clean water. The respondents were also asked if they think they discharge polluted water.

2.5 Perception toward seawater quality

The last part of the questionnaire intends to gauge the environmental awareness among local people. Using visual cues pertaining to seawater quality such as turbidity, greenness and smell, local people perception were obtained, in addition to water quality management issues. Aside from probing the existence of polluted water, the indicators, duration, causes, sources, impacts and effects on personal health of polluted water were also asked. In attempts to find a solution to water quality problem, people were also asked what pollution

mitigation measures could be done and if they are willing to contribute financially to for water quality improvement.

2.6 GPS mapping of household, tourism infrastructure and facilities and GIS Creation

Using a hand-held GPS, households and tourism establishments were located and mapped. The relative locations of these areas with respect to the shoreline were established by walking along and around the extents of residential buildings and tourism establishments. Likewise, open canal and outlets of natural waterways were also mapped. This location data could be used in verifying data generated by image classification through GIS. A GIS database, implemented under ArcGIS platform, was set up to demonstrate how various data can be compiled to provide useful information for monitoring and management. The tourism establishment data obtained from Puerto Galera council were encoded and overlaid on Puerto Galera map derived from Ikonos® satellite image. The name of the hotel, number of rooms, restaurants and other details were included in the list of input details and could be updated anytime. Other results from remote sensing classification, such as built-up and forest cover was added. In GIS, it is also possible to incorporate other water quality data from numerical simulations and measurements. Understanding the relationships among various data and comparison among different sites in Puerto Galera could be realized through GIS analysis.

2.7 Monitoring by remote sensing and land cover change detection

Five Aster and one Ikonos satellite image datasets were acquired. The images acquired from Aster are as follow: Jan 3, 2001; Nov. 3, 2001; Sept. 3, 2002; Feb. 17, 2003 and Feb. 22, 2005. The Ikonos image was taken on Feb. 28, 2006. These images were geo-referenced and were calibrated using empirical line method to achieve common spectral range values for all images. Spectral unmixing technique was used to classify basic land cover, such as built-up, grassland and forest. Based on the results of the image classification of the multi-date Aster images, historical land cover changes and their spatial patterns temporal trends were determined. This information on cover change is important for building up a spatial information database for understanding physical environment dynamics.

3. RESULTS AND DISCUSSION

3.1 Availability of sanitation facilities

Three types of toilet are found in Puerto Galera; flush types, pour-types and latrines. A flush-type toilet is one in which water closet carries the waste down the pipes. A pour-type toilet functions in the same way, but water is poured in manually by a bucket. Waste from either of these toilet types ends up either in septic tank (sealed or open-type), pit or elsewhere through rivers. A latrine or *Antipolo*-type of toilet does not use water at all to flush waste, which goes directly to a pit underneath.

The type of fecal waste disposal facility indicates the level of waste control management. The old type of septic tank in Puerto Galera is an open-type. Here, solid waste and greases for sewage are contained. The wastewater comes out from the sanitary tee outlet and should go to sanitary sewage treatment system but there is no such system in Puerto Galera. Instead the sewage effluent is released into open canal or a body of water. From the year 2002, the local government recommended the sealed-type septic tank for all houses and building constructions. Sealed-type septic tanks does not have sewage effluent outlet but instead allows effluent to leach on its second chamber. Pit is the least environment-friendly among fecal waste disposal facilities. Surveys indicated that advance toilet facilities such as flush-type toilet were found in all tourism establishments in White Beach and in most establishments and households in Sabang and Muelle. However, most households in White Beach had pour-type toilets. This illustrates that sophistication of toilet does not necessarily translate to quality of sewage disposal. The sewage from toilet ended up in sealed-type septic tanks in most establishments located Sabang and in majority of households in Muelle and White Beach. All establishments in White Beach and most establishments in Muelle had open-type septic tanks. Even though most households in Sabang had flush-type toilets, they do not have septic tanks and dispose wastes into individual pit. Generally, flush-type toilet consumes more water to carry down the waste than other types. The combination of flush-type toilet and pit as sewage disposal means may result in greater load of waste to end up into the bodies of water. This is the case of Sabang household sector. The household sectors of White Beach and Muelle and tourism sector of Sabang own better facilities to control pollution in terms of toilet and sewage disposal facilities.

3.2 Local peoples' sanitation practices

Survey of activities involving the use of water by the household sector claimed that water usage was dominantly for food preparation, cleaning/laundry and bathing. In contrast, responses from tourism sector varied among the sites. For White Beach, bathing was the leading activity using water, followed by cleaning/laundry and food preparation. For Sabang and Muelle (though much lesser in degree), cleaning/laundry was the main use of clean water. Among the three tourism sites, Muelle had the least degree of activities related with water usage.

In White Beach, regardless of sector, wastewater is directly discharged on the ground. This was also true for the tourism sectors of Sabang and Muelle. But since the location of the business establishments was along the shoreline, wastewater is almost directly discharged into the sea. On the other hand, the household sectors in Muelle and Sabang discharged wastewater into either open canal or bodies of water. Most establishments from all tourism sites and most people residing in White Beach denied contributing to water pollution. The residents in Muelle and Sabang admitted having contributed to seawater deterioration.

Generally, those people who discharged wastewater into the open canal/bodies of water were aware that they had taken part in polluting seawater. However, most respondents, especially those from the tourism sector, denied polluting the seawater.

3.3 Perception toward seawater quality

Table 1 shows a summary of the key findings in the questionnaires distributed in the three study sites. The duration of water pollution in Sabang as perceived by the people is the

longest (always present). The household sector seemed to be more sensitive to recognizing polluted water than tourism areas. The survey also showed that there is tendency among respondents to point to other culprits for seawater deterioration as in the case of the tourism sector. In terms of impacts, those from the household sector recognized few impacts of pollution. Particular to health effects, it is people of Sabang which experienced the harsh consequence of pollution. Thus, they have gained awareness of water pollution and its negative impacts based on personal experience.

It is interesting to note that the part of the survey related to water quality management received the largest number of responses. Among the household sector, information campaign got the highest response as a measure to improve water quality. The survey also indicated those people who had a previous unpleasant experience with polluted water were the ones who are more willing to contribute for water quality improvement.

Table 1. Summary of key findings in the questionnaire survey represented as a perception matrix. M, S and W represent Muelle, Sabang and White Beach respectively. Table entry represents leading answer.

Parameter teste / **Location**	**Household**			**Tourist establishments**		
	M	**S**	**W**	**M**	**S**	**W**
Seawater quality deterioration	Bad	Bad	Good	Good	Bad	Good
Leading indicator of water pollution	Color	Color	Color	Color	Color	Color
Duration	Day	Always	None	None	None	None
Source of pollution	Local people	Resorts	No answer	Boats	Residents	Boats
Effects of pollution	Aesthetics	Health & safety	Less tourists	No problem	Less tourists	Biota
Experienced health effects	None	Disease	None	None	Disease	None
Water quality management	Local people	Gov't agencies	Gov't agencies	Local people	All	Local gov't
Options to improve water quality	Info Campaign	Education	Facilities	Education	Facilities	Facilities
Willingness to pay (PhP)	Not willing	100	500	Not willing	500	Not willing

Figure 3 show that White Beach water had the best water quality condition among the three sites. Among the three, Muelle had the highest turbidity and Sabang has the highest bluegreen algae content. Plotting the results of water quality measurements against the observations of the local residents in terms of algae and turbidity showed a positive correlation as plotted in Figure 4. The survey results along Batangas channel were added to increase the number of samples. This figure confirms that even without water quality measuring devices, people are capable detecting pollution through sensory perceptions, specifically by visual means. However with the dominance of strong indicators such as turbidity in Muelle and bluegreen algae in Sabang, the respondents overlooked weaker indicators, such as bluegreen algae in Muelle and turbidity in Sabang.

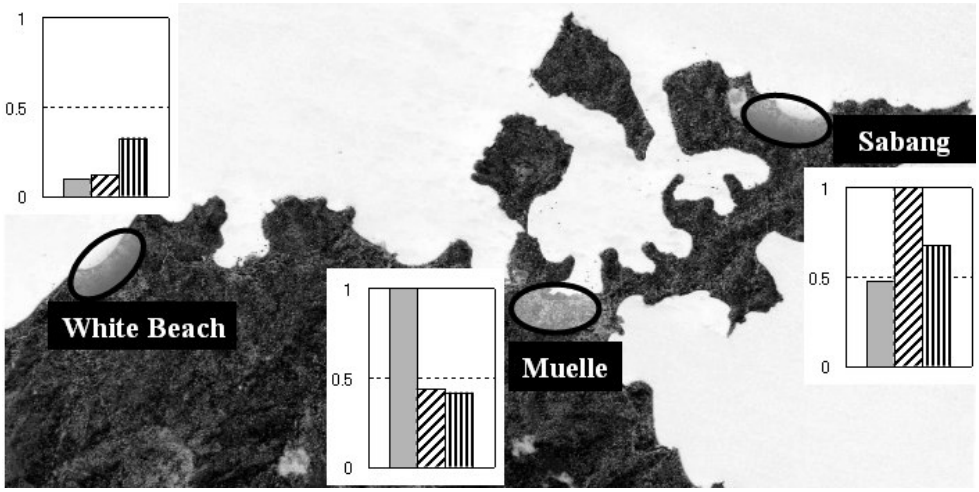

Figure 3. Seawater quality parameters, as measured using data-logging sensors (as discussed in the previous chapter) were plotted in their normalized values. Vertical axis of the graph insets represent normalized values for turbidity (gray), blue-green algae (diagonal line patterns) and chlorophyll-a (vertical line patterns).

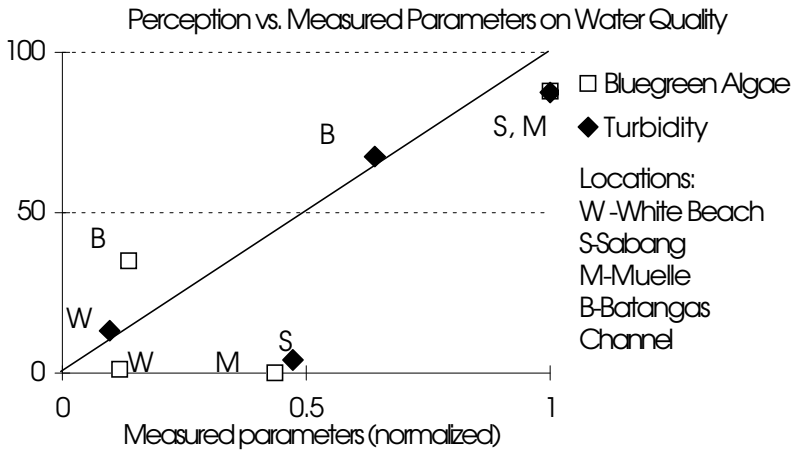

Figure 4. Results of water quality measurements and the observations of the local residents in terms of algae and turbidity showed a positive correlation.

3.4 Monitoring by remote sensing

Classification results of multitemporal ASTER image datasets were overlaid with one another (Figure 5) to show the pattern of land cover change, including built-up expansion through time. Development in Muelle, through increase in built-up area was highly scattered and minimal, about one hectare in four years. In White Beach, there was almost a two-fold increase in four years and built-up areas were dispersed further from the shoreline. In contrast, the expansion of development in Sabang was concentrated along the shoreline. Assuming that accessibility or proximity to the sea is proportional to its impact, then Sabang may pose greater threat to water quality.

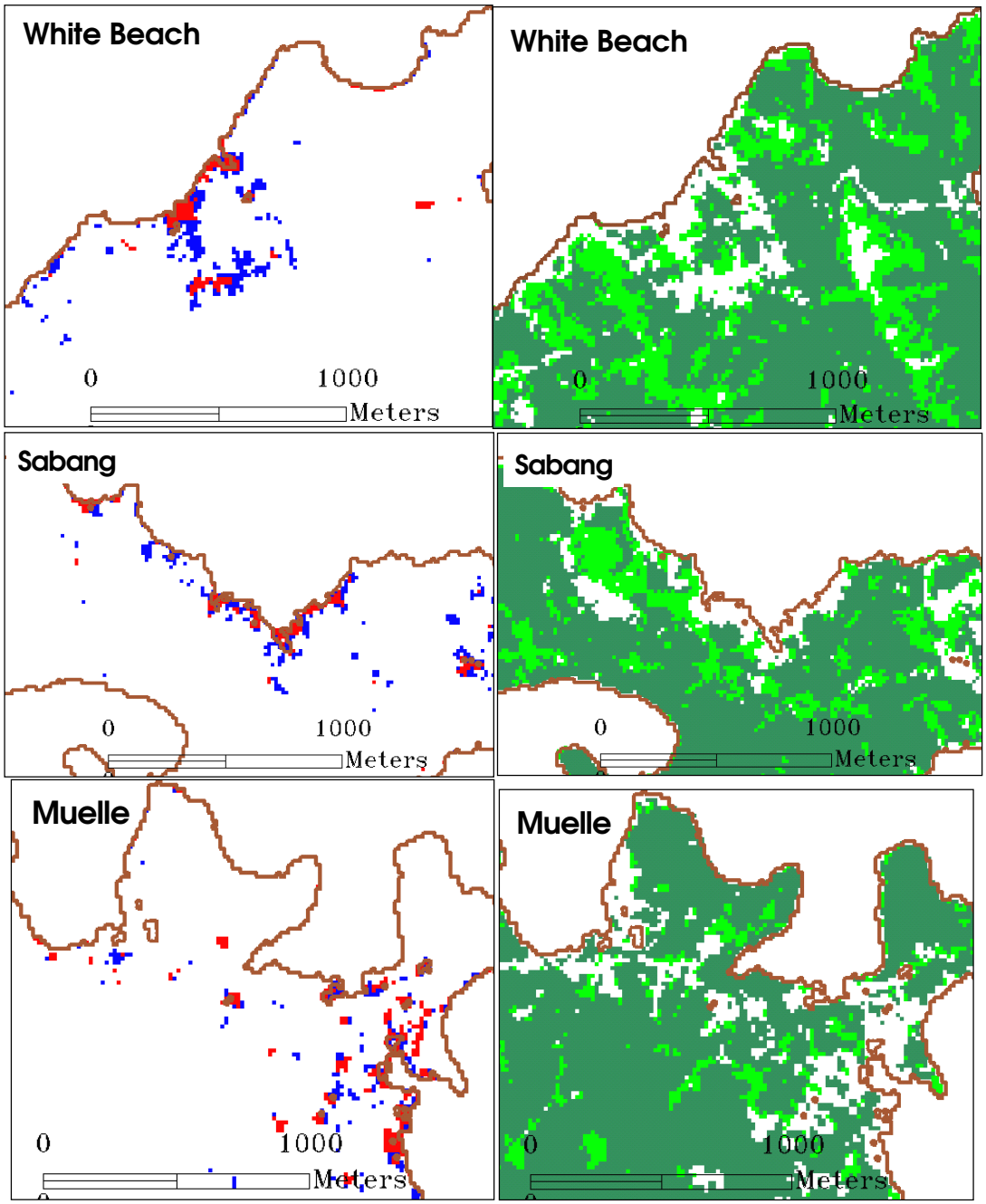

Figure 5. Built-up expansion and land cover change by remote sensing.

In White Beach area, built-up and deforested areas grew 100% resulting in 20% forest cover reduction. On the other hand, land use proportions remained minimal. Probable causes for the variation in the change pattern include dependency of the local people to tourism as sources of livelihood. The people of Sabang are inclined to stay closer to the coastline to involve in businesses related to tourism. On the other hand, the people of Muelle and White Beach have other livelihood activities aside from tourism making it unnecessary for them to dwell long the shoreline.

4. ANALYSIS AND IMPLICATIONS FOR MANAGEMENT

Despite several the construction of new hotels and modern houses to cope with increasing demand of tourism and growing population, sewage collection and treatment facilities in Puerto Galera remain absent, with a number of houses without septic tanks. Despite precarious proximity to the shoreline, tourism establishments, as in the case of Sabang, continue to deny involvement in seawater pollution. Admission of the problem and environmental awareness are fundamental steps towards finding solution to water deterioration problem.

The household sector seemed more sensitive in detecting polluted water probably due to their infrequent visits as compared to the tourism sector, which might become immune because of their daily exposure to the sea. Nonetheless, ordinary people can spot pollution through qualitative indicators. Through additional information campaign and training, these people can conduct water quality monitoring and supplement information derived from specialized sensor measurements.

Survey results still show that not all people think that solution to the water quality problem must be a joint effort. Therefore, confidence-building measures must be conducted among different stakeholders to achieve solidarity. The preference to information campaign as a tool to solve water quality problem reflects the inadequate information about environmental condition and its impacts, and the people's desire to gain further knowledge about their environment. This is also a preventive way of addressing a problem to avoid consequences, such as spread of diseases and loss of tourists, before the actual seawater deterioration becomes inevitable.

Devising a monitoring scheme (whether involving data-logging sensors and people's perception or a combination of both) and developing a good spatial information system incorporating various data sources would serve as a starting point for assessment of environmental condition and would help determine areas needing immediate measures. Further analysis could be derived in the light of all available data through GIS, such as statistical and spatial analysis. Thus, it is possible to maximize the utilization of all existing data for more thorough understanding of the physical and social environment. Collective participation of all sectors in the process of monitoring and planning would facilitate acceptance of any environmental program.

5. SUMMARY AND CONCLUDING REMARKS

There is inadequate facility for sewage collection and treatment in Puerto Galera. However, differences in peoples' sanitation practices, as in the cases of White Beach and Sabang, show variations in seawater pollution levels. The carrying capacity of the sea to absorb wastewater in the three tourism sites examined is affected by the governing hydrodynamic circulation. Continuous monitoring of the seawater quality is therefore necessary to know the various factors involve in water quality deterioration.

Prior to this research, there is inadequate information on the environment and the distribution of social and tourism conditions in Puerto Galera. Use of GPS and satellite remote sensing-based mapping and organizing them in a GIS presented a more comprehensive and integrated view and may help promote environmental awareness and

guide proper management. This study showed that people are capable of perceiving water quality through visual techniques. The desire to learn more about the environment through information campaign are healthy signs that people are willing to contribute for the improvement of the water quality condition. Peoples' perception is important if any recommendations on water quality improvement are to be considered.

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