Stock enhancement of tiger shrimp (*Penaeus monodon*): Studies and assessments for the Batan Estuary in northern Panay Island, central Philippines

(ウシエビの放流：フィリピン・バタン湾における

有効性と可能性の調査)

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1.1. Introduction

This study aims to describe the present situation in the Batan Estuary of northern Panay Island, Philippines in terms of its natural environment, inshore fisheries, and social setting; and assess the prospects, benefits and requirements of tiger shrimp *Penaeus monodon* stock enhancement in the area.

This paper contains four main chapters that start with an introduction and review on the stock enhancement concept and the target shrimp species *Penaeus monodon*. This is followed by chapters on the Batan Estuary environment, fishing communities, inshore fishing status, and specific studies on stock enhancement of tiger shrimp in the Batan Estuary.

Chapter 1 provides background information about stock enhancement, a brief history, existing strategies and methodologies, as well as its prospects and problems. It also introduces the species under study – the tiger shrimp *Penaeus mondon*, its biology, ecology, and importance as a food resource. The chapter also outlines the objectives of this paper and its limitations.

Chapter 2 deals with the study site – The Batan Estuary. Starting with a background presentation on the state of coastal degradation in the Philippines, the chapter aims to present the real situation in the Batan Estuary that may be typical in the country and other developing countries. It shows not only the location and geography of the area, but also the socio-political setting that makes this study site challenging to work on. The investigations conducted for this chapter was mainly concerned with the environment, specifically mangrove forest cover and water condition. Using manual image analyses and actual field surveys, the intense decline in mangroves and shoaling of rivers and lagoons were estimated.

Chapter 3 focuses on the status of inshore fisheries within the Batan Estuary. In the introduction of this chapter, the importance and organization of fisheries industry in the Philippines are presented. It also highlights the significance of municipal or artisanal fisheries in terms of livelihood and employment in the country, and specifically in the Batan Estuary. Through interview surveys, the dependency of local communities on aquatic resources of the area was made clear. Fishers responded, based on personal experiences, that fish and shrimp catch have declined from previous decades and that current income can barely support their families. They also mentioned various other problems that coincided with results in the previous chapter on mangrove decline and water depth changes. To investigate further, actual catch monitoring surveys were conducted to show the intense fishing pressure in the area and the low per capita income based on daily average catch. Results in this chapter include the distribution of overcrowded fishing gears in the estuary, the current catch composition, and the declining trend in production in terms of catch-per-unit-effort or CPUE, especially for shrimps.

It is the decline in wild population of tiger shrimps in the Batan Estuary that the prospect of its stock enhancement in the area was entertained; and this is the main focus in Chapter 4. This chapter begins with a brief introduction on the common objectives of shrimp stock enhancement programs in other countries which are mainly ecological, scientific, or commercial. On the other hand, the general purpose for a similar program in the Batan Estuary may as well be socio-economic in focus, that is, to principally alleviate the state of livelihood of artisanal fishers who are most dependent on shrimp fishing for survival.

Related literature on requirements for stock enhancement is presented, highlighting the need for site-specific and species-specific assessments. Some of these requirements were addressed in this chapter through actual experimental studies on tiger shrimps done on-site or in a nearby laboratory. Important information on source of stocks, pre-release culture method, area of release, optimal age at release, natural shrimp mortality and practical shrimp marking techniques were discussed. With data gathered from these work, pilot stock enhancement trials were supposed to be planned for this research. However, due to unfavourable circumstances like a series of typhoons hitting the study site in the past years, the implementation of the trials was hampered. In addition, other important sub-studies were not conducted as caused by these unforeseen delays and insufficient time and funds. Nevertheless, significant assessments from experiments were noted in the recommendations for future studies.

In the last chapter, Chapter 5, a more thorough discussion and synthesis of results are presented. Based on results from previous chapters, the main problems in the Batan Estuary can be summarized into three main points. First, poverty situation among local fishers is worsening brought about by low quality and quantity of harvest, especially of shrimps. Secondly, the intense overfishing in the area is evident with overcrowded fishing gears, overrunning the natural regeneration of fish and shrimp stocks. Third, the natural environment was extremely degraded where more than 92% of mangroves have been destroyed, mostly converted into aquaculture ponds, and depriving the wild aquatic population of their natural habitat. These issues suggest three logical recommendations which are (1) to increase fishers' income, (2) to reduce number of fishing gears, and (3) to rehabilitate mangroves. It is with these ideas where shrimp stock enhancement is viewed to be beneficial. Succeeding sections in this chapter show the significance of stock enhancement of tiger shrimp *Penaeus* *monodon* in the Batan Estuary. It illustrates the concepts that make shrimp stock enhancement a viable tool in addressing the key concerns mentioned above.

Lastly, the reality of declining shrimp fisheries and the worsening state of natural environment in the Batan Estuary are reiterated in the concluding remarks. The prospects of tiger shrimp stock enhancement in the area are high and the benefits are clear, provided that the recommendations outlined in this chapter be taken into consideration prior to actual implementation of the program. Importantly, the support of sectors like the government, local universities, people's organizations, stakeholders, and local fishers must be solicited to create unbiased management plans.

This study has made some important scientific contributions, where there are currently only very few studies on stock enhancement specific for *Penaeus monodon*. Basic concerns like source of stocks, rearing methods, optimal age of shrimps at release and practical tagging methods were determined for the Batan Estuary. Still, many other studies are recommended to be conducted such as genetic considerations, health management, risk assessments, bio-economic modelling, and social impact studies. Although, the actual stock enhancement activity was not realized within the duration of this study, the results and information gathered, especially on the current status of the Batan Estuary, are crucial for future programs, management and legislations. It is also an important recommendation in this study to consider a more social and community-based approach towards stock enhancement initiatives in the future.

1.2. Stock enhancement

1.2.1. Background and definition

In the past decades, the world's wild fisheries resources seem to have reached its peak, where current capture fisheries production have been almost constant (Fig. 1-1). This has been brought about mainly by excessive capture fisheries, recreational fishing, pollution, habitat degradation and even climate change (FAO 2006; Pauly 1988; Pauly 2002; Pomeroy 2006; Molony et al. 2003; Brown & Day 2002; Morgan 2001; Bell et al 2005; Beamish and Noakes 2004). These resources are now severely threatened and will continue to be degraded from increasing and varied forms of destruction (Wilkinson et al. 2006). Wilkinson et al. (2006) added that although Marine Protected Areas (MPAs) and other fisheries control strategies have already been developed in some areas, the effectiveness of marine resources management remains inconsistent; thereby the conjecture of improving natural stocks is vague. In addition, the pressure on aquatic resources is not expected to subside quickly because people are strongly dependent on coastal zones (Weinstien et al 2007), especially in developing countries in Southeast Asia like the Philippines. Resource dependency in these regions is complex due to high natural productivity of tropical coastal ecosystems, creating multiple economic niches for coastal residents (Bailey and Pomeroy 1996). These complexities in social structure and natural resources partitioning are the challenges in modern fisheries management in ensuring both food security and environmental conservation.

The stagnancy in wild fisheries production poses a threat to the ever growing human population, reaching close to seven billion by the end of the current decade (Fig. 1-1). In addition, the demand for fish and aquatic products is expected to rise even more by year 2020 (Bell et al. 2006). Aquaculture has been providing volumes of fish and fisheries products since the eighties (Fig. 1-1), most especially from China in the recent years (FAO 2009). Aquaculture is playing a major role in supplying world's increasing demand for fish (Tacon 2003; Muir 2005). However, environmental issues and problems with aquaculture have been raised, pinpointing the negative effects of conversions of mangrove areas to other uses (Primavera 2005), pollution from wastes and effluents (Primavera et al. 2007), and even direct effects on reducing wild fish populations (Naylor et al. 2000). Ultimately, the question is not only on whether or not we will have enough fish to eat in the future, but also on whether or not we will still have natural aquatic resources and healthy coastal zones. This is where the idea of aquatic stock enhancement comes in; not only to increase fish yield for food, but also to compensate losses caused by human's interventions to nature, and to promote environmental rehabilitation and conservation.

Stock enhancement has been named and defined in various ways, depending on varied criteria (Table 1-1). Terms like restocking, sea ranching, coastal mitigation, augmentation, and addition have been used interchangeably in the past because of similarity in function – to increase population of stocks in the wild. However, only two main concepts have been recently recommended, namely: (1) *restocking*, release of cultured juveniles to restore spawning biomass to levels where the fishery can once again support regular harvests, and (2) *stock enhancement*, referring to the release of cultured juveniles to overcome recruitment limitation (Bell et al. 2006; Loneragan et al. 2006). Based on these two, the concept of "stock enhancement" will be used in this study because the initial priority will be to increase stocks primarily for production and income generation. The "restocking" concept would eventually follow, after conducting more comprehensive studies and management to allow the released stocks to reach reproductive maturity and ultimately enhance natural recruitment.

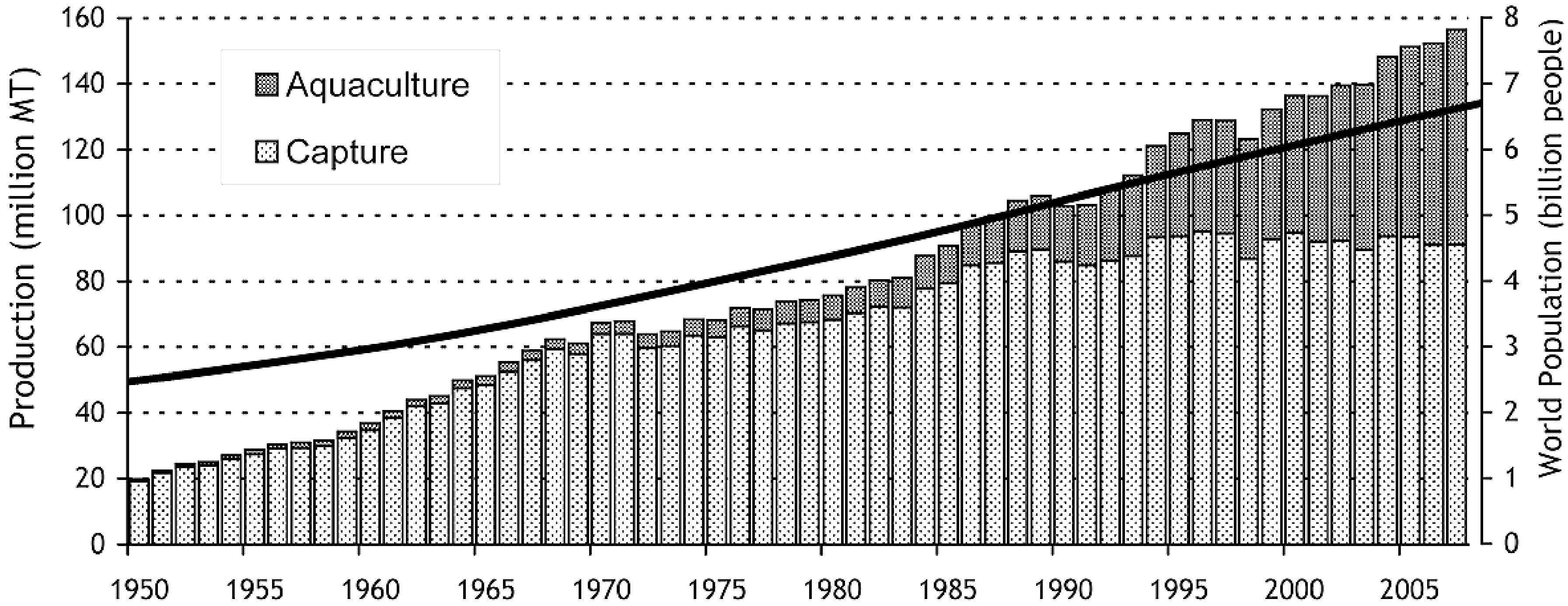

Figure 1-1. Trend in global capture fisheries and aquaculture production (in million metric tons) from 1950 to 2007 (FAO 2009) and the steady human population growth of the world (in billions) from 1950 to 2010 (U.N. 2009).

Table 1-1. Some terms and definitions for stock enhancement (after Bannister, 1991)

Term	Definition	Reference
Stock enhancement	- Release of cultured juveniles to overcome recruitment limitation	Bell et al (2006)
	- Production and release of fish for public good	Drawbridge (2002)
	- Supplementing natural recruitment with hatchery produced fry	Ziemann (2001)
	- Production and release of fish for inter-generational benefit	Harada and Matsumiya (1992)
Restocking	- Releasing cultured juveniles to restore spawning biomass to levels where the fishery can once again support regular harvests	Bell et al (2006)
	- Production and release of hatchery-reared fish into an area where the species historically occurred but are now rare or extinct	Bannister (1991)
Mitigation	- Production and release of fish to restore stock to original levels	Radtke and Davis (2000)
	- Stocking of fish into new/modified habitat to compensate for a decrease in a fishery	Cowx (1994), Bartley (1999)
Sea/Ocean/ Marine Ranching	- Production and release of fish for common good	Drawbridge (2002)
	- Releasing of fish to the ocean to grow relatively unassisted to be commercially harvested	Arnason (2001)
	- Production of early life- stages of species in a hatchery for eventual release into natural or modified habitats	Bartley (1999)
	- Production and release of fish to recover stocks to historic levels	Blaxter (1994)

Table 1-1 continued…

Term	Definition	Reference
Augmentation	- Production and release of fish to compliment natural recruitment where available habitat is below carrying capacity	Cowx (1994), Bartley (1999)
	- Production and release of fish at a size where missing key habitats are no longer a limiting factor	Bannister (1991)
Addition	- Stocking of a new species into an area outside of its natural range	Rowland (1994)
	- Stocking of a new species into an area outside of its natural range	Bannister (1991)
Enhance	- Production and release of fish to create new fisheries	Petr (1998)
	- Production and release of fish to increase stocks above original levels	Radtke and Davis (2000)
Habitat enhancement	- Production and release of fish to artificially decolonize new/artificial habitats	Young (1999)
Community change	- Production and release of exotic fish to create new fisheries	Cowx (1994), Bartley (1999)

1.2.2. History of stock enhancement

As a positive fisheries management tool and to boost fishing production, scientists and fisheries managers have been looking at ways of enhancing fish stocks for more than a century (Blaxter 2000; Molony et al. 2003; Liao 1997). Since then, well over than 300 species were estimated to have been used for release worldwide (Welcomme and Bartley 1998a), and 290+ of these are freshwater (Welcomme 1992), signifying that marine restocking is relatively uncommon (Brown and Day 2002). In Japan alone, about 80 species are being ranched or researched for eventual stocking (Fushimi 2001; Salvanes 2001).

Early records of release initiatives dated back to 1867 with shads (*Alosa sapidissima*) in New England (Stickney 1996) and chum salmon (*Oncorrhynchus keta*) in Japan in 1876 (Oshima 1993). In 1884–1985, USA and Norway also initiated stock enhancement of fin fishes (Liao 1999). The first salmon hatchery in the United States was established in the 1870s (Blankenship and Leber 1995) and the release of marine finfish followed, including the Atlantic salmon, flounder, haddock, cod and pollock (Blaxter 2000; Leber 2004). Meanwhile, the earliest record of stock enhancement activities in Europe was the release of plaice in Norway and Scotland in 1882 and 1894, respectively and transplants of the same species in the Baltic and North Seas in 1893 (Blaxter 2000). Since then, many other attempts and programs for stock enhancement followed. Some of other finfish species released were the striped mullet *Mugil cephalus* (Leber et al. 1995; Leber et al. 1996), red drum *Sciaenops ocellatus* (Bert et al. 2003), Pacific salmon (Beamish and Noakes 2004), coastal cod *Gadus morhua* (Moksness 2004), common snook *Centropomus undecimalis* (Brennan et al. 2005), and red snapper *Lutjanus campechanus* (Blaylock et al. 2000).

Stock enhancement of invertebrates like mollusks also started as early as 1900 for scallops in Norway, but was more commercially implemented starting 1970 in Europe and Japan (Salvanes 2001). Specifically, scallops *Patinopecten yessoensis* were produced for release in Japanese waters (Kitada 1999). Other species released, including echinoderms, were queen conch *Strombus gigas* (Ray et al. 1994), topshell *Trochus niloticus* (Crowe et al. 2002), abalone *Haliotis iris* (Schiel 1993), sea urchin *Strongylocentrotus intermedius* (Agatsuma et al. 2003), and sea cucumber *Holothuria scabra* (Dance et al. 2003). Other than as food resource, endangered species were also reseeded for conservation purposes like the giant clams *Tridacna* spp. (Mingoa-Licuanan and Gomez 2002) and sea horses *Hippocampus* spp. (Okuzawa et al. 2009).

Crustacean stock enhancement programs also started early, like the release of newly-hatched eggs and newly-settled juveniles of the European lobster *Homarus gammarus* in southern Norway in 1889 (Salvanes 2001). Crabs has also had extensive release studies such as blue crabs *Callinectes sapidus* (Davis et al. 2005; Zmora et al. 2005), *Portunus trituberculatus* (Okamoto 2004), mud crab *S. tranquebarica* (Secor et al. 2002), and other *Scylla* species (Le Vay et al. 2008; Lebata et al. 2009). Shrimp stock enhancement has also started since the 1960s in Japan with *Penaeus japonicus* (Fushimi 1999; Kitada 1999), and since 1980s in China with *Penaeus chinensis* (Wang 2006). Unlike other species, however, crustacean stock enhancement programs were relatively few because of various problems in monitoring brought about by tagging difficulty due to molting. More details on shrimp stock enhancement are discussed in succeeding sections.

Although stock enhancement activities have been done more than a century ago, the approach during those early times can be categorized as being focused on "production" where the main concern was achieving higher release volume and magnitude (Leber 1999). Moreover, the advent of stock enhancement activities was started with the simplistic idea that production could be increased by releasing eggs or larvae of a certain species into coastal or marine waters (Welcomme and Bartley 1998b). The period governed by this simplistic notion was branded as the "denial phase" by fisheries scientists after recognizing that stocking programs lack the evidence of positive effects on capture production due to little emphasis on understanding its impact on fisheries landings (Leber 1999). However, later programs have shown to replenish depleting stocks for commercial fisheries, as well as in game fishing in countries like the USA (Leber 2004), Norway (Moksness 2002), Japan (Kitada 1999), and Taiwan (Liao 1999). It is only at these times, or about a decade ago, where the "science" of marine stock enhancement began when critical thinking emerged and scientific objectives and hypotheses were formulated (Leber 1999).

1.2.3. Objectives, strategies and requirements

Stock enhancement programs vary in objectives and reasons for implementation. Bartley (1999) summarized that these were undertaken mainly for three purposes: (1) *mitigation* – to compensate for some decrease in a fishery due to another type of development activity; (2) *augmentation* – to make the fishery more productive by increasing the number of fish present; and (3) *community change* – involving the use of exotic or introduced species not normally part of the local fish community. While Cowx (1999) defined four main reasons for stocking, namely: (1) *mitigation* – a voluntary stocking exercise as a fishery protection scheme after some environmental perturbation like dam construction, land drainage works, etc.; (2) *enhancement* – a principal method used to maintain or improve stocks where production is actually, or perceived to be, less than the water body could potentially sustain, but where reasons for the poor stocks cannot be identified; (3) *restoration* – carried out after a limiting factor to stock recovery or improvement has been removed or reduced, like water quality improvement or habitat restoration; and (4) *introduction* – attempts to establish a new stock that was not previously present because of natural barriers or evolutionary isolation, or where new exotic species are introduced into existing fisheries in an attempt to increase diversity or improve yield.

Alongside these objectives, approaches and strategies for stock enhancement programs also vary. Welcomme and Bartley (1998a) mentioned that there are two main strategies for management and enhancement of inland water resources, and these can be differentiated between strategies implemented in “developed” and “developing” countries (Table 1-2). Stocking strategies in “developed” countries are geared towards ecological goals, particularly the enhancement of recreational fisheries and protection of species diversity (Cowx 1998). In fact, the preference for sports fishing which are predominantly in developed countries, has led to early adoption of enhancement techniques and these were usually coupled with some form of habitat maintenance and conservation (Welcomme and Bartley 1998a). These programs are also heavily subsidized by the government like in the cases of Japan (Kitada 1999) and the USA (Leber 2004). Government hatcheries are capital intensive and the associated aquaculture techniques are also intensive in design, industrialized, and employ the latest technology and gearing towards higher returns and profit.

On the other hand, such programs in “developing” countries are mostly economically-driven, specifically for food security and income generation which also involve some form of habitat modification and intensive broadcast of seeds (Welcomme and Bartley 1998a). This concept is exemplified by stocking projects in China (Wang 2006), Taiwan (Liao 1999), Sri Lanka (Davenport 1999), and

Table 1-2. Differing strategies between developed and developing countries (after Welcomme and Bartley 1998a)

	Developed Countries	Developing Countries
Objectives	Conservation	Provision of food
	Recreation	Income generation
Mechanisms	Sport fisheries	Food fisheries
	Habitat restoration	Habitat modifications
	Environmentally-sound stocking	Intensive restocking
Economic	Intensive, modern aquaculture	Extensive, rural aquaculture
	Capital-intensive	Labor-intensive
	Profit	Production

India (Sunugan 1995). In contrast with strategies in developed countries above, aquaculture efforts to support stock enhancement in developing countries are extensive but labor-intensive, rural in nature, and lack enough funding for infrastructure development despite adequate physical potential of the area (Welcomme and Bartley 1998a).

Whatever the purposes and strategies defined for stock enhancement, it is most important to consider various scientific aspects to ensure the applicability and feasibility of such programs in achieving those goals. In contrast with the way release programs were conducted in the past, modern stock enhancement activities would benefit more by incorporating a more scientific approach. Given the long history of questionable stocking practices, and because of rapidly expanding interest worldwide in starting new programs, it is essential to apply a substantial amount of science towards solving several key constraints to responsible application of stock enhancement technology (Blankenship and Leber 1995). To develop an effective and sound stock-enhancement tool, the integration and coordination of research and expertise in several essential sub-disciplines of natural science and social science are imperative. For a successful stock enhancement program, the biology and ecology of target species must be thoroughly understood from production of seed stocks until monitoring and assessing the efficiency of release, as well as the conditions of the environment for release, carrying capacity of the habitat, wild populations and diversity, factors that may contribute to mortality, and existing fisheries (Rothlisberg et al. 1999; Fushimi 2001; Liao et al. 2003). Therefore, basic studies need to be followed and tested prior release (Table 1-3). Similarly important are the roles of fisheries managers, local governments, and especially the local fishing communities for effective and responsible stocking program (Bell 2002; Garaway 2006; Liao 2003).

Table 1-3. Fundamental studies on stock enhancement (adapted from Liao 1999)

Category	Required studies
Fisheries survey	(1) Collection of fisheries statistics (2) Investigation of local environment
Biology of target species	(1) Distribution (2) Sex ratio (3) Fecundity (4) Biological minimum size (5) Feeding habits (6) Recruitment (7) Growth and commercial size (8) Life span
Mass production techniques of target species	(1) Broodstock cultivation (2) Larval rearing (3) Facility automation for production (4) Feed (natural and formulated)
Methods of live transport of target species	(1) Transport duration (2) Transport method (3) Costs and labor requirements
Nursery techniques of target species	(1) Optimum size (2) Optimum season (3) Optimum density (4) Suitable feeds (5) Predator control
Environmental improvement for target areas	(1) Natural ecosystems (2) Artificial reefs (3) Protective zones (4) Fish paths and fish ladders (5) Water quality and pollution control
Release and recapture investigation	(1) Biodiversity (2) Assessment methods (a) Population genetics (b) Tagging experiments (c) Catch data
Management and regulation	(1) Prohibited fishing periods (2) Prohibited fishing zones (3) Prohibited fishing gears and methods (4) Defined penalty

The varying levels of success in stock enhancement programs around the world have resulted in various research concerns and scientific information generated has emphasized the importance of physiological, biological, morphological, and ecological attributes of the hatchery-reared juveniles (Fushimi 2001) and their behavior, adaptations, and survival in the wild (Bell 2005). Consequently, Liao et al. (2003) recommended that the current research thrusts on stock enhancement and restocking must be focused on: improved techniques for mass production of seedstock and juveniles for release; release strategy; production of pathogen-free stocks and health management; efficient tagging methods including genetic markers; ecological observations on carrying capacity and its effects on success rate; mathematical modeling; and socio-economic analysis.

Another key in ensuring successful stock enhancement and restocking programs is following some pre-determined guidelines for systematic planning, implementation, monitoring and management. Blakenship and Leber (1995) have made a 10-point system for a responsible approach to developing, evaluating and managing marine stock enhancement programs that includes the following: (1) prioritize and select target species; (2) develop a species management plan that identifies harvest opportunity, stock rebuilding goals, and genetic objectives; (3) define quantitative measures of success; (4) use genetic resource management to avoid deleterious genetic effects; (5) use disease and health management; (6) consider ecological, biological, and life-history patterns; (7) identify released hatchery fish and assess stocking effects; (8) use an empirical process for defining optimum release strategies; (9) identify economic and policy guidelines; and (10) use adaptive management. Similarly, such guidelines can be presented into flowcharts that can be easily followed and comprehend (Fig. 1-2, Fig. 1-3).

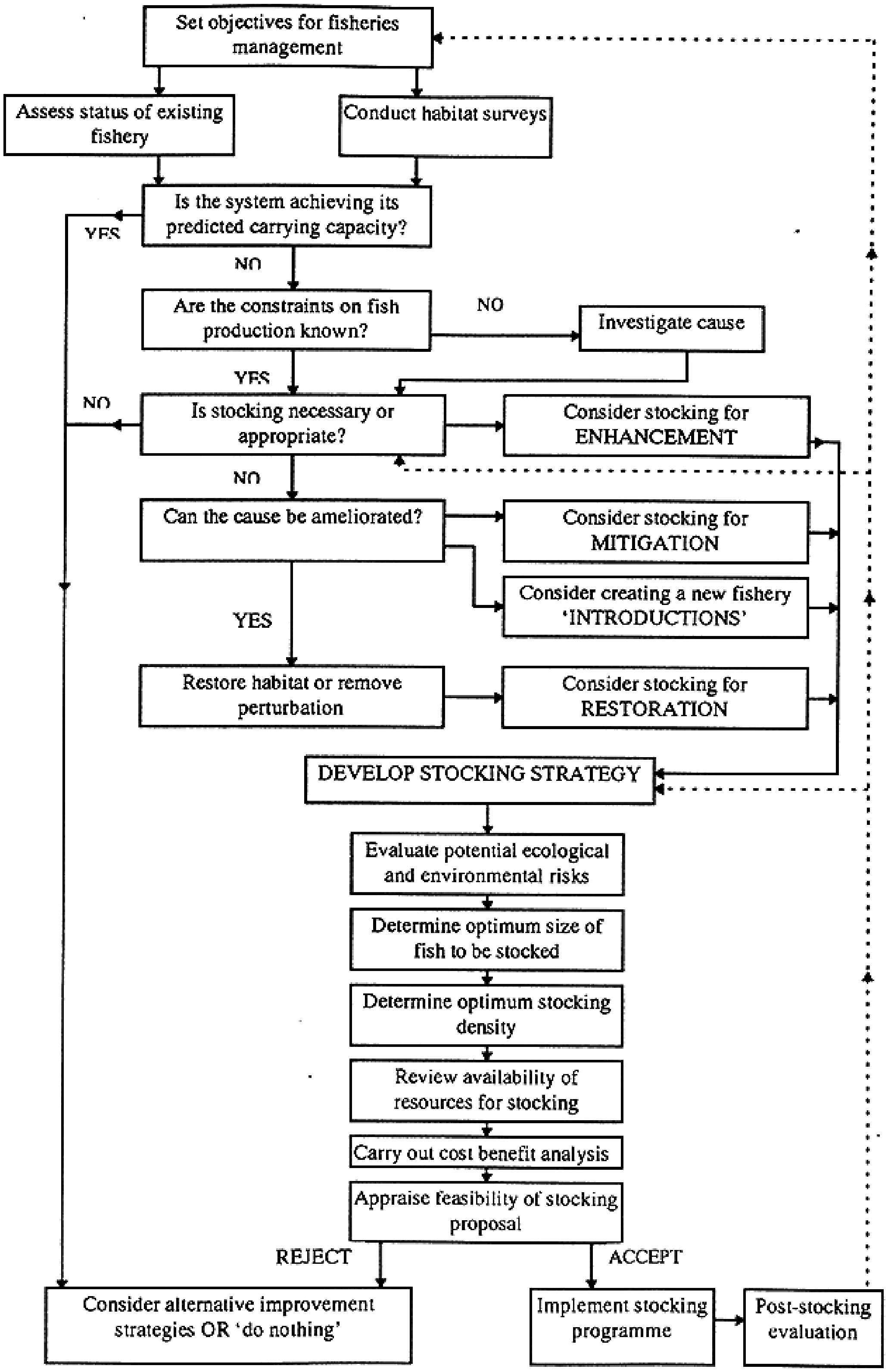

Figure 1-2. Suggested strategy for evaluating stock enhancement programs (after Cowx 1994)

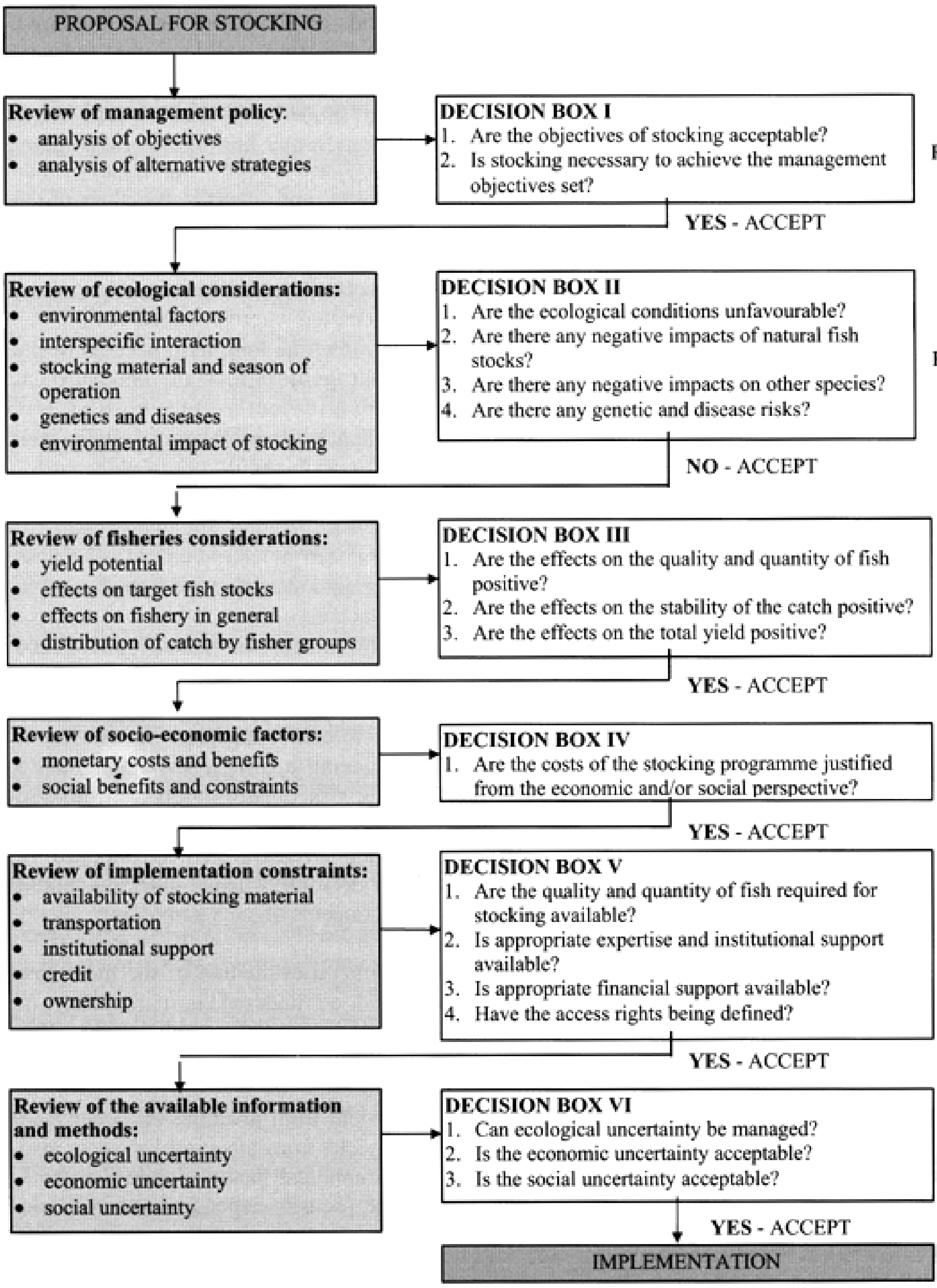

Figure 1-3. Schemes for planning stock enhancement programs. On the left are levels of data collection and processing; while on right are respective decision levels. Stocking should be rejected if any answer to the questions are unacceptable (adapted from EIFAC 1994; Cowx 1999)

It is reiterated here that stock enhancement or restocking programs need to have clear and specific objectives. Then after some initial assessments, guided by scientific criteria, the strategies to be used must be defined. After which, another series of studies must be conducted which are specific for the site and species in question. Bell et al (2006) emphasized that preliminary assessments should be carried out before investments on research and construction of facilities, and before any alternative management options are dismissed or delayed in lieu of stock enhancement. Additionally, Lorenzen (2005) promoted that studies on population dynamics and bioeconomic modeling in combination with participatory approaches in planning and implementation can provide a broad-based assessment of alternatives and help avoid unrealistic expectations and biased views and decisions.

1.2.4. Problems and progress

Many studies have mentioned that stock enhancement studies were conducted extensively in many countries, mostly unscientifically, for more than a century but the success of these programs were apparently absent and unquantifiable (Liao et al 2003; Welcomme and Bartley 1998b; Bell et al 2006; Cowx 1999). The long-lived constraint of stock enhancement or restocking activities is not only the lack of proof of success in terms of harvest and ultimate production, but also in terms of natural ecology, and effects on social dynamics of local fishing communities.

In many cases, release of stocks in the wild was done because of surplus in supply of hatchery-bred and reared individuals originally for aquaculture, like for shrimps in Japan and China (Fushimi 1999; Wang 2006). This has become a popular method of supplementing depleted stocks (Bert et al. 2003). However, the capability to produce abundant seeds from hatcheries and aquaculture farms is not enough reason to release juveniles and call it stock enhancement (Bell and Nash 2004). Moreover, hatchery operation often only accounts for large quantities of seed production, rather than producing good quality and ecologically viable individuals (Fushimi 2001; Brown and Day 2002). Without careful considerations, these haphazard releases would eventually result to critical loss of stock fitness through genetic introgressions (Allendorf et al. 1987; Cross 1999; Ward 2006; Utter 1998), negative interactions of released stocks with wild species and alter trophic dynamics (Cowx 1998), and transfer of diseases (Bartley et al 2006; Daszak et al 2001).

On the other hand, problems with the local fishing communities can also arise because fisheries management programs, including stock enhancement, entail some kind of social modification, like fishing limitations (Altamirano and Kurokura 2008). Blankenship and Leber (1995) also summarized that to effectively recondition depleted stocks, fishing effort must first be regulated; second, degraded nursery and spawning habitats must be restored; and third, only then can stocks be replenished through stock enhancement or restocking. However, Lenanton et al. (1999) reported that there is an inherent danger of restocking the depleted resources. Should restocking or stock enhancement be successful, and increase in catch realized, there is the desire to continue such activity over longer periods, creating the tendency to overlook the original subtle causes of decline, and therefore will still remain unsolved. In this case, the local communities will continue to rely on this artificial and virtual solution, rather than the ultimate goal of having naturally sustainable aquatic resources. Therefore, stock enhancement or sea ranching should not be seen as a substitute for the long-term conservation and management of valuable aquatic resources (Liao et al. 2003).

Scientific studies and research on stock enhancement have been done in the recent years, but are only mostly aimed towards reducing cost of producing ecologically fit juveniles from hatcheries and to increase survival of released stocks, hoping that only these aspects can make stock enhancement or restocking viable (Howell et al 1999; Blaxter 2000; Laber et al 2004; Bell et al 2005). However, current progress in research also involves various other concerns such as basic biology and ecology of target species (Fushimi 2001), health management (Bartley et al. 2006), risk assessments (Ye et al. 2005), socio-economic studies (Hallenstvedt 1999), as well as social science perspectives (Garaway et al. 2006).

1.2.5. Shrimp stock enhancement

Prawns or shrimps, especially in the family Penaeidae, are fished heavily throughout the world (Loneragan et al. 2006). Trends in shrimp capture fisheries show some decline in the recent years especially in South America, Europe and Japan, although China's production have dramatically increased (Fig. 1-4). There has also been published report of specific decrease in natural shrimps stocks of *Penaeus esculentus* in Australia (Penn and Caputi 1986; Wang and Die 1996), *Penaeus setiferus* and *Penaeus duorarum* in Mexico (Gracia 1996; Ramirez-Rodriguez et al., 2000), and most especially of *Penaeus chinensis* and *Penaeus orientalis* in China (Liu, 1990; Wang et al. 2006) and kuruma prawns *Penaeus japonicus* in Japan (Fushimi, 1999; Hamasaki and Kitada 2006). This decline has been compensated, in most part, by aquaculture, where a lot of penaeid shrimp biology and ecology have been known (Rothlisberg 1998), and enhanced by the resilience of their life history strategies, e.g., fast growth, high fecundity, and early maturity (Dall et al., 1990). Shrimp aquaculture production has increased particularly in the Americas and in China, but other regions still experience some decline like in Europe and Japan (Fig. 1-5).

The main problem in aquaculture, however, is the difficulty of growing prawns of shrimps into maturity in captivity (Rohthlisberg 1998). Most spawners in hatcheries are still sourced from the wild (Primavera and Menasveta 1996; Goman et al. 2007). The overfishing of shrimps eventually results in the reduction of wild broodstock. Recruitment-overfishing has been attributed to the decline in *P. setiferus* and *P. esculentus* in Exmouth Gulf, Australia (Penn and Caputi, 1986). The same is also viewed for *Penaeus chinensis* in China (Wang et al. 2006). This evidence of recruitment over-fishing in prawn fisheries led to a re-evaluation of the paradigm that the dynamics of prawn stocks were largely influenced by environmental variation (Loneragan et al. 2006). Recently, a meta-analysis of a range of prawn populations concluded that prawn recruitment was related to the abundance of spawners, and that prawn populations should be managed to maintain sufficient mature adults to yield high recruitment (Ye, 2000).

The decline in shrimp fisheries, and the uncertain sustainability in aquaculture, coupled with high demand and commercial value for prawns or shrimps, has initiated the interest into shrimp stock enhancement programs. Since the early 1960s, the release of numerous shrimp larvae and juveniles has been done in various countries (Table 1-4). The aim of these restocking was primarily to increase available shrimps in the wild for capture fisheries as in the USA, Kuwait, Sri Lanka, and Taiwan (Bell *et al*., 2005). In Japan, the loss of natural coastal habitats and nurseries caused by industrialization since the 1960s has affected wild seeds recruitment, hence the need for artificial restocking of shrimp juveniles (Hamasaki and Kitada, 2006). Like in Japan, China has excess seeds produced for aquaculture and these were used for

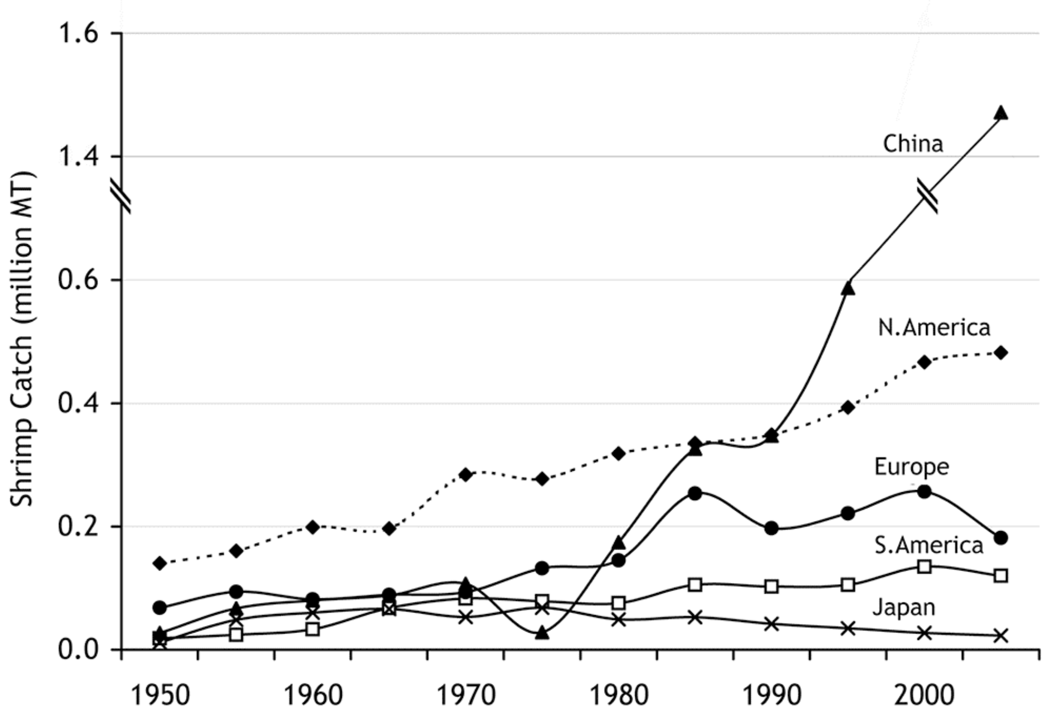

Figure 1-4. Trends in global shrimp capture production (data from FAO, 2009)

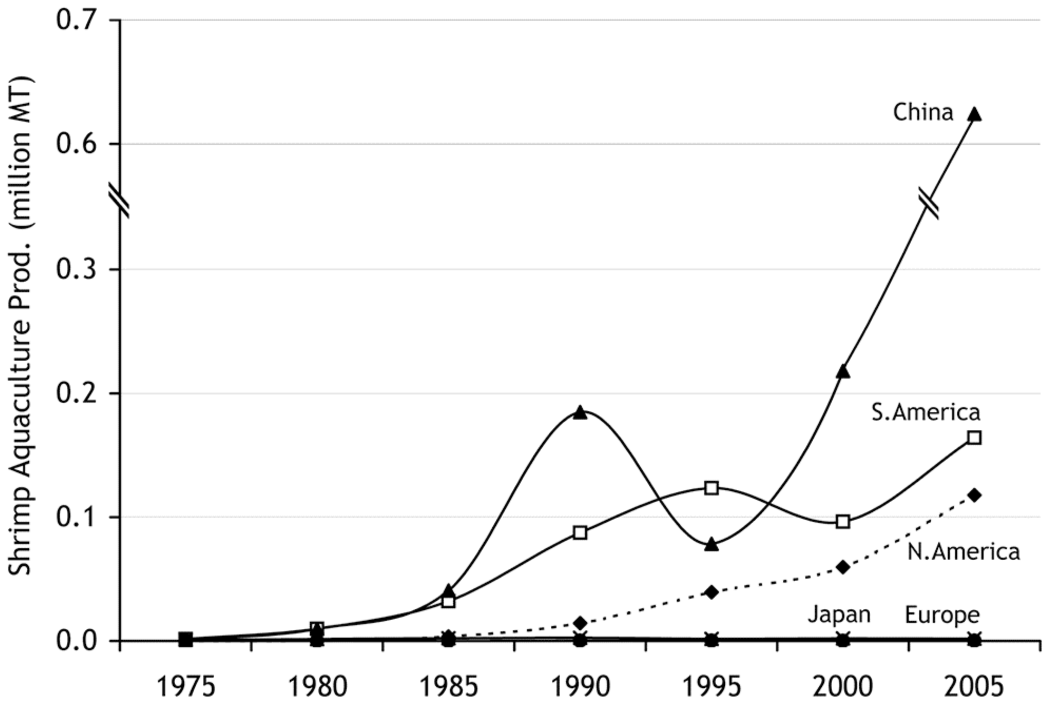

Figure 1-5. Trends in global shrimp aquaculture production (data from FAO, 2009)

Table 1-4. Penaeid shrimp stock enhancement programs (adapted from Bell et al., 2005)

Species (country)	Years	Location	Scale of releases (M = million, B= billion)	Reference
P. japonicus (Japan)	1964 onwards	All Japan	200–300M	Kurata (1981), Kitada (1999), Fushimi (1999)
		Seto Inland Sea	100–150M	Tanida et al. (2002), Miyajima and Toyota (2002)
		Hamana Lake	2–11M	Fushimi (1999)
P. chinensis (China)	1980s onwards	Bohai Sea	1 B (max = 2.2 B)	Liu (1990), Xu et al. (1997), Wang et al. (2006)
		Northern Yellow Sea	800M (max = 2.2 B) 300M (max = 520 M)	
		Southern Shandong	800M (now 300 M)	
P. aztecus *P. setiferus*, *P. duorarum* (U.S.A.)	1971–1974	Florida	16–52M 3–137M	Kittaka (1981)
P. semisulcatus, *Metapenaeus affinis*, *P. japonicus* (Kuwait)	1972–1978	Kuwait	4–25M	Farmer (1981)
P. monodon (Taiwan, Sri Lanka)	1983–1984 1995–1997	Taiwan Rekawa Lagoon, Sri Lanka	6,340 (sub-adults) 55,000–70,000	Su and Liao (1999) Davenport et al. (1999)
P. esculentus (Australia)	2001–2002	Exmouth Gulf, Australia	250,000	Loneragan et al. (2003, 2004)

release in the wild (Wang et al. 2006). The decline in production of the usual species may also trigger the introduction of a new commodity to support fisheries like in the stock enhancement of *Penaeus monodon* after the decline in catches of *Peaneus indicus* in Sri Lanka (Davenport 1999). Stock enhancement projects in Australia were also done to verify new methods and technology (Loneragan 2006). Despite the many attempts at prawn stock enhancement, releases currently occur only on a large scale in Japan and China where there are large aquaculture industries with the capacity to produce billions of prawn "seeds" for release into coastal waters (Xu et al. 1997; Fushimi 1999; Hamasaki and Kitada 2006; Wang et al. 2006). Most of the programs on shrimp stock enhancement have been done primarily to increase commercial catches and fisheries production. These are often in the order of tens of thousands to millions of released shrimps that are supported and subsidized by the government.

Current research and programs on shrimp or prawn stock enhancement and restocking show the importance of systematic studies to identify optimal release strategies for hatchery-reared juveniles including the significance of site, size and density at release on the survival of released prawns, as well as effective marking and monitoring procedures (Loneragan et al. 2006). Also, bioeconomic models and risk assessment for all components of a stock enhancement operation, i.e. hatchery, grow-out, releasing, population dynamics, fishery, and monitoring are also important (Ye et al. 2005. For example in Exmouth Gulf in Australia, Ye et al. (2005) predicted that a release of 21 million of 1 g prawns would produce an estimated enhanced prawn catch of about 100 t with an estimated 66.5% chance of making a profit.

1.3. The tiger shrimp *Penaeus monodon*

1.3.1. Taxonomy and morphology

The taxonomic hierarchy and nomenclature for *Penaeus monodon* is as follows:

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Crustacea

Class: Malacostraca

Subclass: Eumalacostraca

Superorder: Eucarida

Order: Decapoda

Suborder: Dendrobranchiata

Superfamily: Penaeoidea

Family: Penaeidae

Genus: *Penaeus*

Species: *Penaeus monodon*

The species *Penaeus monodon* was originally described by Fabricius in 1798 (Suppl. Ent. Syst., 408), and has been synonymous with related species like *Penaeus carinatus* Dana 1852, *Penaeus tahitensis* Heller 1862, *Penaeus coeruleus* Stebbing 1905, *Penaeus bubulus* Kubo 1949, and has been often confused with *Penaeus semisulcatus exsutcatus* Hilgendorf 1879. *P. mondon* has been commonly called as the giant tiger prawn (English), Crevette géante tigrée (French), and Langostino jumbo (Spanish). It is also called as the tiger prawn in S. and E. Africa, *kamba* in Kenya, *kalri* in Pakistan *bagda chingri* in India, *ushi-ebi* in Japan, grass shrimp in Taiwan, ghost shrimp in Hong Kong, jumbo tiger shrimp or *sugpo* in the Philippines, *udang windu* in Indonesia, and in Australia as black tiger prawn, blue tiger prawn, giant tiger prawn, jumbo tiger prawn, leader prawn, and panda prawn (Holthuis 1980).

Similar to all penaeid shrimp, the rostrum of *P. monodon* is well developed with 7-8 dorsal teeth and 3-4 ventral teeth (Fig. 1-6). The cervical and orbito-antennal sulci and antennal carinae are always present and the main carapace has no longitudinal or transverse sutures. Hepatic and antennal spines are pronounced and pterygostomain angle round. Stylocerite is located at first antennular segment. Basial spines are on the first and second pereiopods and exopods are located on the first to fourth pereiopods usually present. Telson has no fixed subapical spines. Adrostral sulcus and carina are short and not reaching posteriorly beyond midlength of carapace. Gastrofrontal carina is absent in this species. Females have closed-type thelycum, while petasma in male is symmetrical with thin median lobes. According to Holthuis (1980), the most distinct features for identification of this species are (1) fifth pereiopods without exopod; (2) hepatic carina horizontally straight; and (3) gastro-orbital carina occupying the posterior half of the distance between hepatic spine and postorbital margin of carapace. External body coloration on *P. monodon* varies depending on substratum, kind of food and water turbidity. Color shade ranges from green, brown, red, grey, blue and transverse band colours on abdomen and carapace are alternated between blue or black to brown and yellow.

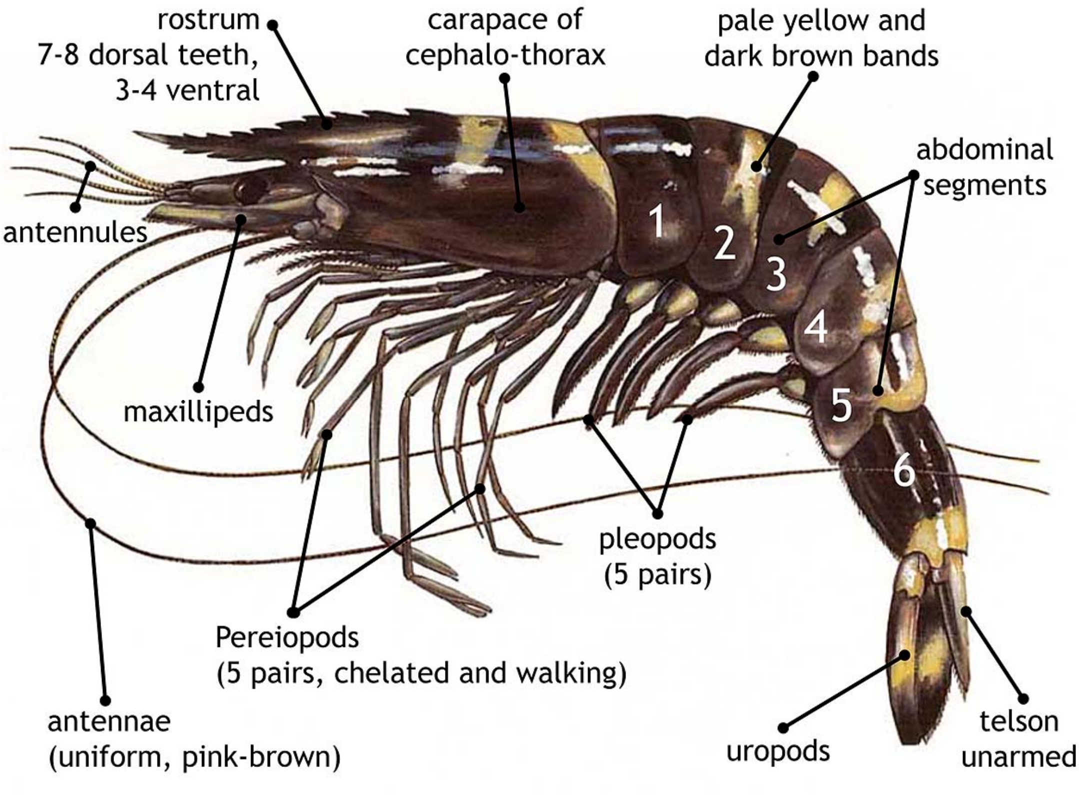

Figure 1-6. External morphology of tiger shrimp *Penaeus monodon*

1.3.2. Life cycle and ecology

Penaeus monodon mature and breed only in tropical marine habitats and spend their larval, juvenile, adolescent and sub-adult stages in coastal estuaries, lagoons or mangrove areas (Fig. 1-7). In the wild, they show marked nocturnal activity, burrowing into bottom substratum during the day and emerging at night to search for food as benthic feeders (Primavera and Lebata 1995). Under natural conditions, the giant tiger prawn is more of a predator than an omnivorous scavenger or detritus feeder compared to other penaeid shrimp. After moulting, the new shell is still soft which causes prawns to become vulnerable and they may subsequently be eaten by their predators or cannibalized by companions. Adults are often found over muddy sand or sandy bottoms at 20-50 m depth in offshore waters. Wild males possess spermatozoa from around 35 g body weight and females becomes gravid from 70 g. Mating occurs at night, shortly after moulting while the cuticle is still soft, and sperm are subsequently kept in a spermatophore (sac) inserted inside the closed thelycum of the female. There are five stages in ovarian maturation; undeveloped, developing; nearly ripe; ripe; and spent. *P. monodon* females are highly fecund with gravid females producing as many as 500 000 to 750 000 eggs. Spawning occurs at night and fertilization is external with females suddenly extruding sperm from the thelycum as eggs are laid in offshore waters. Hatching occurs 12-15 hours after fertilization. The larvae, termed nauplii, are free swimming and resemble tiny aquatic spiders. This first stage in larval development does not feed but lives on its yolk reserve and passes rapidly through six moults. The next larval stages (protozoea, mysis and early postlarvae respectively remain planktonic and are carried towards the shore by tidal currents. Protozoea, which have feathery appendages and elongated bodies, moult three times and then metamorphose into the mysis stage. Mysis, which have

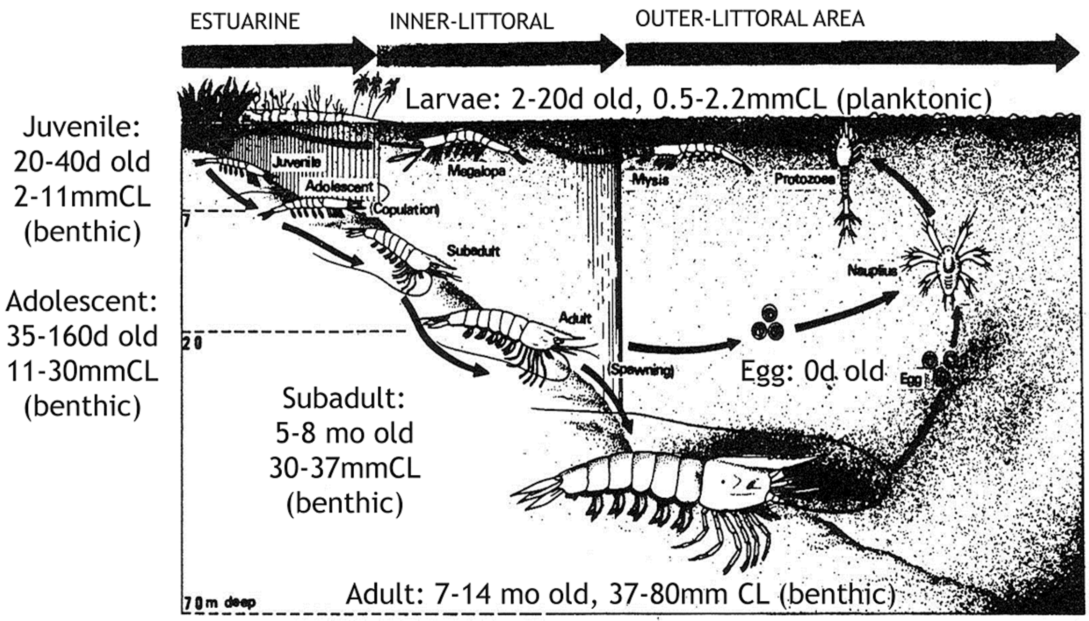

Figure 1-7. Schematic representation of the life cycle of tiger shrimp *Penaeus monodon* showing main stages with corresponding duration in days and body size in carapace length (after Motoh 1981).

segmented bodies, eyestalk and tails characteristic of adult shrimp, also moult three times before metamorphosing into PL with similar characteristics to adult shrimp. Adults reach 33 cm in length and weigh 60-130 g, with females commonly larger than males (Holthius 1980). Nursery and growout *P. monodon* showed a greater weight gain per unit length than adult broodstock and size dimorphism appeared only at the broodstock stage with bigger females; while males and females showed similar sizes in nursery and growout stages (Primavera et al. 1998).

P. monodon is a euryhaline species and is known to osmoregulate its haemolymph strongly over a wide range of salinity and has an isosmotic range between 20 and 30 ppt (Cawthorne et al., 1983; Solis 1988). Juvenile and adolescent stages can tolerate salinity conditions as low as 1-2‰. Like other penaeid shrimps, *P. monodon* larvae migrate from the sea to mangrove areas where salinities are much lower and food is abundant (Turner 1977; Newell et al. 1995; Mohan et al. 1995; Kathiresan and Bingham 2001; Sasekumar et al. 1992; Chong et al. 1996; Primavera 1998; Rajendran and Katherisan 1999, 2004). Although shrimps population were not directly related to organic content abundance, shrimps still prefer fringe mangroves than adjacent sand flat (Ronnback et al. 2002). In an experiment to assess diel behavior, large and medium *P. monodon* prefer to use shelters mostly in the day while smaller shrimps prefer to burrow; and they spend 70-90% time feeding at night (Primavera and Lebata 1995).

Penaeus monodon is a large brackish water-marine prawn widely distributed throughout the tropical Indo-Pacific region (Cawthorne 1983). The giant tiger prawn is mostly distributed along the coasts of East and South Eastern Africa and Pakistan to Japan, the Malay Archipelago and whole of Southeast Asia, and northern Australia (Fig. 1-8).

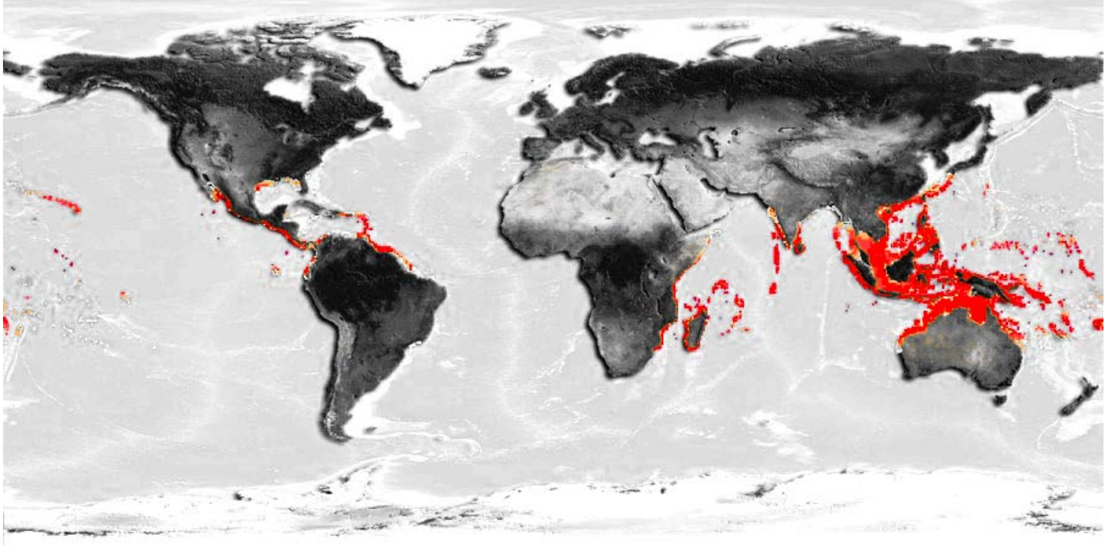

Figure 1-8. Global estimated distribution (red dots) of tiger shrimp *Penaeus mondon*. Data collated by Aquamaps [www.aquamaps.org] Dec 11, 2009; data from Global Biodiversity Information Facility (GBIF) [www.gbif.net] and Ocean Biogeographic Information System (OBIS) [www.iobis.org].

1.3.3. Fisheries and aquaculture

Fisheries in the tropics and subtropics often focus primarily on penaeids, and secondarily on finfishes and are characterized by fishing one major cohort with strong seasonal patterns (Ye 1998). It is obtained by pond, inshore and offshore fishing in Malaya, Singapore, Indonesia, the Philippines and Taiwan because its large size the species is quite important economically. It is being harvested as far north as Japan and to the south in Australia, and the countries with the largest catches were India and Indonesia (Holthuis, 1980). *Penaeus monodon* capture production dramatically increased since the late 1980s but has slowed in the recent decade (Fig. 1-9). It composed 7.5% of the 3.2 million MT total global shrimp and prawn capture production in 2007 (FAO 2009).

The increasing demand for tiger shrimps has been compensated by the established aquaculture of this species (Fig. 1-9). Shrimp farming has been practiced for more than a century for food and livelihood of coastal people in some Asian countries, such as Indonesia, the Philippines, Taiwan, Thailand and Viet Nam (Kongkeo 1997; Limsuwan and Chanratchakool 2004. From 1970-1975, research on breeding was conducted and monoculture techniques in small ponds were gradually developed at the Tungkang Marine Laboratory in Taiwan and partly at the IFREMER (Centre Océanologique du Pacifique) in Tahiti in the South Pacific (Kongkeo 2001). In Thailand, extensive and semi-intensive farms were commercially established in 1972 and 1974 respectively, after the first success in breeding *P. monodon* at Phuket Fisheries Station in 1972 (Limsuwan and Chanratchakool 2004). In Taiwan, tiger shrimp culture started in 1968 when artificial propagation of seeds was established, surged and peaked at 95,000 mt in 1987, but plunged by 70% in 1988 as caused by viral diseases (Lo, 2003; Liao et al. 1989).

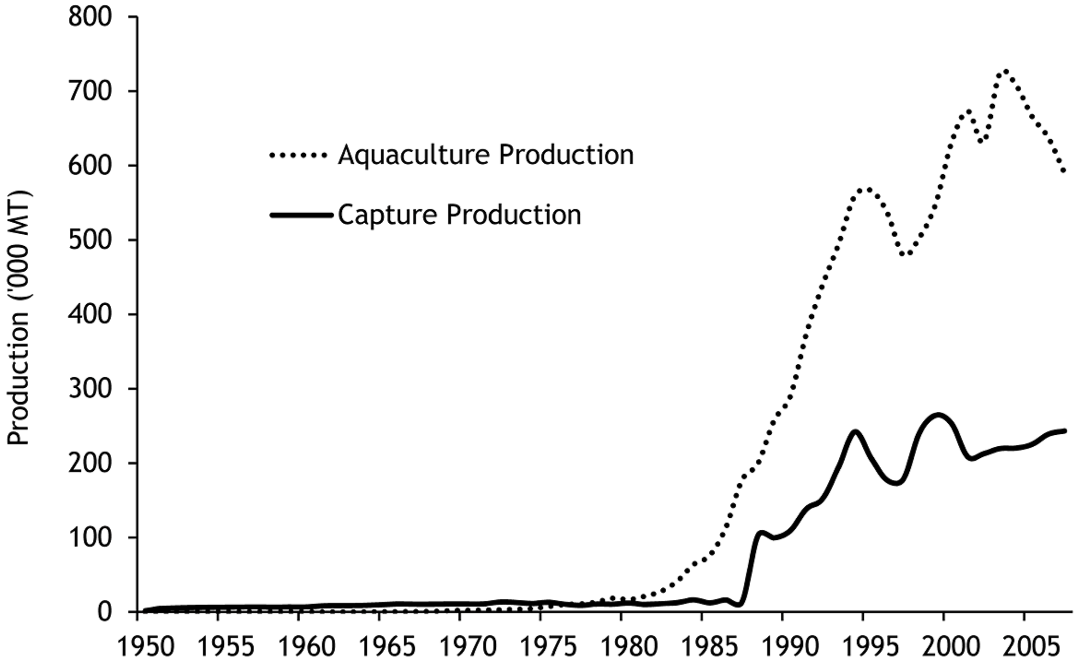

Figure 1-9. Global aquaculture and wild capture fisheries production for *Penaeus monodon* (FAO 2009)

This collapse in Taiwan tiger shrimp aquaculture, and driven by extremely high prices in the Japanese market due to supply shortages, has given the chance to Thailand to be the world's leading producer of cultured *P. monodon* in 1988 (Limsuwan and Chanratchakool 2004). Adaptation by local Thai farmers has guided them to overcome serious disease, environmental and trade problems (Chanratchakool 1993). Later, the culture of this species spread throughout southeast and south Asia, with high value and demand in the international market.

Tiger shrimp *Penaeus monodon* is one of the most important shrimp species currently being cultured commercially in many countries (Wickins 1976), especially in Southeast Asia (Chen 1998; Ye et al. 2009). It has attracted attention for aquaculture studies because of its high survival and good growth rate (Forster and Beard 1974; Cawthorne 1983). They can tolerate a wide range of salinity from 1 psu to 57 psu (Chen 1990). Although *P. monodon* has a suitable salinity range of 10 psu to 35 psu (Liao 1986), farmers believe that the growth of shrimp in lower salinity water is better than in seawater (Wang and Chen 2006), possibly to minimize effects of diseases. Reports already showed successes of rearing tiger shrimps in freshwater in late seventies in the Philippines (Pantastico 1979), and in rivers, irrigation channels and ground water in the inland area of Thailand (Raghunath et al. 1977). However, the optimum salinity for the culture of *P. monodon* appeared to be ~25 psu, where the average energy budget was: 100 C (100% energy consumed in food) = 14.51 growth 66.68 respiration + 14.54 feces + 3.33 excretion + 0.93 exuviae (Ye et al. 2009).

Penaeus monodon accounted for 58% of the total shrimp production of close to 700,000 mt from farms worldwide in 1995 (Rosenberry 1996). Also, it composed 18% of the 3.3 million mt total shrimp aquaculture production in the world in 2007 (FAO 2009).

Techniques for rearing this species from hatching to commercial size have been well established (Chen 1993). However, despite the long history of rearing *P. monodon*, the introduction or importation of wild broodstock is still commonly practiced because domestication technology has not yet been commercially developed for the species (Coman et al. 2007). Aside from wild broodstocks and spawners, wild seeds are also used commonly collected from coasts in Asia for extensive ponds, which require minimal numbers for stocking. However, collection of shrimp fry from the wild has also been reduced due to overfishing and the outbreak of white spot disease in shrimp nursery grounds; thus most *Penaeus monodon* grow-out farms now rely solely on hatchery-produced seeds (FAO 2007).

The processes in tiger shrimp production from hatchery breeding, nursery, and grow-out culture have been practiced worldwide, and are summarized here in Figure 1-10. In order to provide practical and effective technical guidance for shrimp hatchery management, it is first necessary to review the basic requirements for an effective hatchery production system. FAO (2007) outlined and discussed the following to be the most important requirements:

1. essential infrastructure
2. facility maintenance
3. inlet water quality and treatment
4. wastewater treatment
5. maintenance of biosecurity
6. development of Standard Operating Procedures (SOPs)
7. use of the Hazard Analysis Critical Control Point (HACCP) approach
8. responsible use of chemicals
9. assessment of health status of stocks through laboratory testing

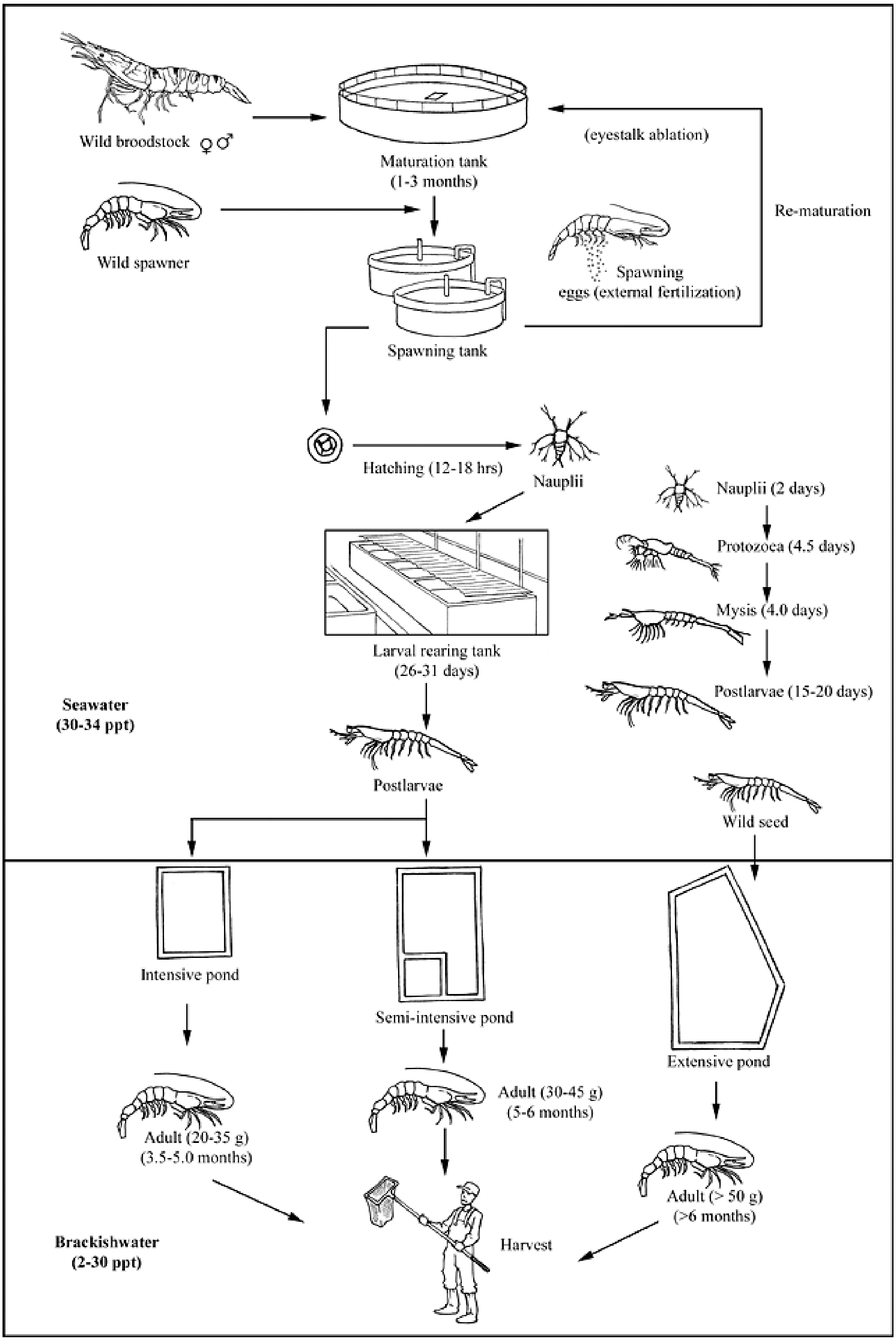

Figure 1-10. Production cycle of *Penaeus monodon* from hatchery breeding to grow-out culture and harvest (after FAO 2007)

There are three on-growing culture practices: extensive, semi-intensive and intensive, which represent low, medium, and high stocking densities respectively. Extensive culture is often rural in nature and uses minimal numbers of wild-sourced postlarvae stocked at about 2 m^{-2} and may yield 50-500 kg ha^{-1} yr^{-1}. Shrimps grow to more than 50 g and harvested after six months or more. They mostly depend on natural foods that enter the pond regularly on the tide, but sometimes added with fresh fish or molluscs and may be enhanced by organic or chemical fertilizers. Semi-intensive ponds use hatchery-reared shrimps and stocked at 5-20 PL m^{-2} into earthen ponds 1-5 ha in area. With natural food enhanced by fertilization and artificial diets, shrimps grow until 30-45 g within 5 to 6 months, and produces yields of 500 to 4,000 kg ha^{-1} yr^{-1}. Simple water management is employed through tidal water change that may also be aided by pumping. Intensive farms employ delicate management that includes heavy aeration, water circulation system, and complete draining and drying of smaller ponds (0.1 to 1.0 ha) prior to stocking of hatchery-produced shrimps at 20-60 PL m^{-2}. Feeds are exclusively artificial diets supplied 4 to 5 times daily. Shrimps are harvested within 3 to 5 months with smaller shrimp sizes of about 20 g, but production yields are commonly between 4,000 to 15,000 kg ha^{-1} yr^{-1}.

Although, rearing and production of cultured *P. monodon* have been done for decades, some urgent issues still need to be studied and improved: (1) Domestication technology, which also leads to the efficient development of disease-free broodstock similar to those for *Litopenaeus vannamei*; (2) vaccination and effective treatment of shrimp viruses; (3) replacement of non-environmental friendly and costly fishmeal and Artemia in shrimp feeds; and (4) efficient water treatment system for closed systems (FAO 2007).

1.4. Objectives of the study

1.4.1. General Objective

The main objective of the study was to establish the current conditions in the Batan Estuary of northern Panay Island, central Philippines in terms of its natural environment, social structure, and focus on inshore and shrimp fisheries; and to assess the prospects, benefits and preliminary requirements of tiger shrimp *Penaeus monodon* stock enhancement for the Batan Estuary.

1.4.2. Specific Objectives

This study has the following specific objectives:

1. To assess the general status of the Batan Estuary, specifically on water area properties and mangrove cover.
2. To determine the social structure around the Batan Estuary and determine the local people's perception on the conditions of the area.
3. To assess the status of inshore fisheries in the Batan Estuary, in terms of total and shrimp catch, fishing pressure and current problems; and establish a trend by comparing with previous surveys.
4. To evaluate the applicability and possible benefits of shrimp stock enhancement in the Batan Estuary.
5. To conduct preliminary site-specific studies on some shrimp stock enhancement requirements for the Batan Estuary.
6. To propose relevant recommendations for the rehabilitation of the Batan Estuary and for future shrimp stock enhancement programs.

CHAPTER 2

THE BATAN ESTUARY

CHAPTER 2

THE BATAN ESTUARY

2.1. Introduction

2.1.1. The big picture

The coastal zones are known to be very productive areas and human beings have long been dependent on resources provided by the coasts (Weinstien et al. 2007). Particularly in Southeast Asia with high natural productivity of tropical coastal ecosystems, coastal resource dependency is very high that this condition usually creates multiple economic niches for coastal residents (Bailey and Pomeroy 1996).

In the Philippines, being an archipelago of 7,107 islands, coastal zones are considered to be the most important areas for residence and livelihood, especially for more than half of the country's 90 M people living in the rural areas (Altamirano 2009). With recent trends however, the Philippine coastlines that were once abundant with fishery resources and vast coral reefs, sea grasses and mangrove belts, have been increasingly depleted (Kuhlman 2004).

Coastal resources are mainly being represented by fisheries production, specifically by nearshore fishing or what is called as municipal fisheries in the Philippines. Although statistics shows that total municipal fisheries production in the Philippines has an increasing trend (Table 2-1), still a number of important fishing grounds in the country have shown significant decline in resources in the past years. General fish production in Manila Bay, for example, declined since 1990 with decreasing species composition, and declining number of large commercial species to be replaced by smaller fish and juveniles (Evasco 2000). The San Miguel Bay in Camarines Sur, Northeast Luzon also showed similar declining trend even since the early 1980s (Mines et al. 1986; Smith et al. 1983). Even the inland lake Laguna de Bay experienced a 67% decline in total fish production from 8,146 MT in 1995 to only 2,668 MT in 1996 (Palma et al. 2002). In the Visayas, particularly in Region 6 (Fig. 2-1) that includes Panay Island, dwindling municipal fisheries production has also been experienced (Table 2-1). In Eastern Panay, the Banate Bay showed a dramatic decrease in coastal resources where municipal catch dropped from 1.2 metric tons in 1991 to 0.9 metric ton in 1996 (Overseas 1998). Although Banate Bay is already recovering after successful coastal management programs (NEDA 2005; Fernandez et al. 2000), the threat of diminishing coastal resources as well as degrading environment in a local and municipal scale was clearly exemplified.

The treat on coastal resources is eminent being brought about by various forms of destruction (Wilkinson et al. 2006). The specific examples given above have one commonality – the alteration of the natural coastal environments. Destruction of mangroves, construction of vast aquaculture ponds, and structures like ports and housing built along the coasts all contributed to these alterations. Intense overfishing and construction of numerous fishing gears in coasts, bays, lagoons and rivers have negatively affected the natural dynamics of these waters, thus, ultimately contributing to the decline in natural fisheries production.

This study focuses on one important coastal zone and fishing ground in central Philippines located in northern Panay Island – the Batan Estuary in the province of Aklan. This estuary exemplifies a typical rural coast – with various resources and various conflicts. It supports a population that is almost solely dependent on coastal and estuarine fisheries (Babaran et al. 2000; Añasco and Babaran 2001). Reports show that this was once a very rich and productive area (FAO et al. 1981; Babaran et al. 2000; Ingles et al. 1992) with lush mangrove forests and a healthy environment that supported diverse population of animals and birds (Altamirano 2007). Presently however, people claim of a deteriorating environment where mangrove forests have been declining and rivers and lagoons becoming shallower. The present paper discusses key changes in this estuarine coast that occurred in the past decades that may have been the main causes for the decline in fisheries resources especially within the estuary.

2.1.2. Objectives

To evaluate the observations cited above about the Batan Estuary, investigations with actual field surveys were conducted. In this chapter, some aspects of the Batan Estuary environment were investigated using simple and cost-efficient methods and aim to present the following:

1) Changes in mangrove cover from the 1950s

2) Physical water conditions in the bay, lagoons and rivers

3) Change in water depth from 1979 and the present

Table 2-1. Municipal fisheries production (Metric Tons) in the Philippines and Region 6* from 1997-2003.

	1997	1998	1999	2000	2001	2002	2003	2004	2006
Philippines' Total	924,466	891,146	926,339	945,945	969,535	988,938	1,055,143	1,080,764	1,235,182
Region 6*	136,536	126,695	132,625	134,227	135,928	127,406	129,672	135,237	140,239

Source: BAS, 2002; BAS, 2004; BFAR, 2006

*Region 6 is a governmental subdivision composed of six provinces located in central Philippines (Fig. 2-1).

2.1.3. Study site

The Batan Estuary (central coordinates 11°35'N and 122°29'E) in Aklan is a semi-enclosed estuarine system composed of lagoons and rivers with a total water area of 2,640 ha. It is composed of three main water bodies – the Batan Bay, *Tinagong Dagat* (translated as "The Hidden Sea") lagoon, and major tributary rivers (Fig. 2-1). The Batan Bay is the center of the estuary directly receiving saline water from Sibuyan Sea through a 600-m wide channel that serves as the sole marine water source for the whole system. The only other river opening was a northern channel in Barangay Tambak, New Washington (Fig. 2-1) that eventually closed some 15 years ago through sand accretion and reclamation for human settlements. From upland, fresh water flows through a number of rivers and creeks, but most drain down to form the major tributary rivers – the upper *Lagatik* River and the lower *Pinamucan* River from the northwest and the *Tinago* River from the southwest. This whole area is being referred to with different names like Batan-*Tinagong Dagat* Estuary, Northeast Panay Wetland, or simply Batan Bay. In this paper, however, this whole site including the outer and inner lagoons, rivers, mangrove areas and aquaculture ponds shall be collectively referred to as the Batan Estuary that covers a total area of about 8,000 ha.

2.1.4. Socio-political setting

The Batan Estuary is wholly governed by the Province of Aklan but the resources are primarily being utilized and managed by three municipalities or towns namely: (1) New Washington to the north, (2) Batan in the middle, and (3) Altavas to the south. The Municipality of Batan has jurisdiction to about 60% of the estuary's waters (Rodriguez 1997) but the Municipality of New Washington covers close to half of the estuary if mangroves and ponds are to be included.

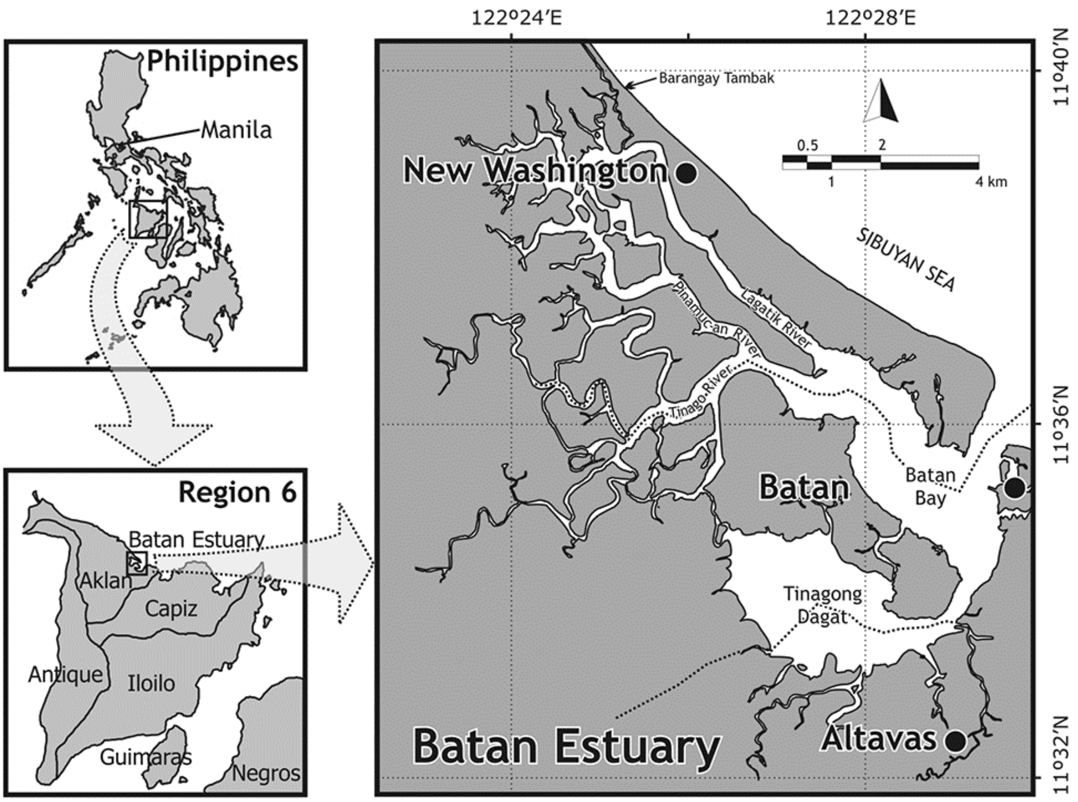

Figure 2-1. The Batan Estuary is located in Region 6, in the northern coast of the triangular island called Panay. It is divided into three major municipalities (New Washington, Batan and Altavas) of Aklan province; their respective center of local government is marked here with “●”. Municipal boundaries are shown with dotted lines. The main water bodies and rivers are also labeled above.

Although a national Fisheries Code is being implemented, these three separate local governments have their own set of specific fishery laws, local ordinances, and management setup (personal observation). These differences sometimes cause conflicts among fishers especially in rivers that are being shared by two municipalities.

In the Philippine social system, a municipality is headed and governed by a mayor and an assembly of council advisers with legislative functions. The municipality is further sub-divided into smaller villages called *barangay* headed by a Barangay Captain and eight other councilors. The three municipalities in the Batan Estuary have a total of 29 coastal *barangays* (12 in New Washington, 12 in Batan, and 5 in Altavas) excluding those far inland that do not share aquatic resources.

According to the National Statistics Office (NSO), collective population of the three main municipalities increased by about 25% every decade since the 1940s but recently slowed down to only 10% from 1990 to 2000 (Table 2-2). NSO (2006) also tagged the three towns as having a general annual population growth rate of 1.36%.

2.2. Methods

2.2.1. Mangrove mapping

The Batan estuary was once covered with lush mangrove forests, but in the recent decades has showed signs of degradation (Altamirano 2007). Field survey and observation in this site were conducted since June 2006, but actual mapping and assessment was done in August to October 2008.

Manual GPS ground tracking by walking along the forest's perimeter (Altamirano et al. 2010) was also considered, but the Batan Estuary has a much wider area with scattered mangrove patches which makes manual GPS survey impractical. For this, image classification was attempted from available maps and images.

Table 2-2. Population growth of three municipalities (Altavas, Batan and New Washington) around Batan Estuary (NSO, 2006)

Year	Population (actual census)	% growth from previous decade
1940	30,840	
1950	38,322	24 %
1960	46,757	22 %
1970	53,675	15 %
1980	66,955	25 %
1990	76,388	14 %
2000	84,366	10 %

The purchase of expensive high resolution satellite images for the recent mangrove cover estimate was avoided, so only freely available sources were considered like images from 2001 LandSat ETM+ scans (www.landcover.org), color images from Google™ maps (maps.google.com), and available aerial photographs. Free LandSat images provided fair resolution but its monochrome nature proved to be difficult for manual classification of vegetation. Composite bands forming color output of the same image was only available at a much lower resolution, hence, classification was more taxing. Likewise, Google™ map images were only available at low resolution for the study area and therefore were not used. An available color digital aerial photograph of the area taken in early 2008 was also considered. Although the resolution was limited to 10 m per pixel, the true color rendering showed important features of ponds and vegetation and were clear and easy to differentiate even with the naked eye.

Inherent problems in aerial photographs require adjustments involving geo-correction and ortho-rectification that maybe automated by software like ERDAS (Mount et al. 2003). However, for the purpose of finding cheaper alternative techniques, manual image correction was done using Adobe Photoshop (ver. 9) software. The color aerial photograph was loaded in Photoshop with decreased opacity. A reference topographic map (the same map used above) was also loaded in the background layer. Manual geo-correction was carefully done using minute adjustments in scaling, skew, rotation, distortion and warp of the aerial photograph to exactly match the features (especially of river banks and islets) on the topographic map. Then the corrected photo was imported to OziExplorer, calibrated and geo-coded using known ground control points before importing again into GPSMapEdit. Because features like rivers, ponds, dikes and vegetation were easily discernible from the photo, manual classification and digitization of mangrove outlines and other features were relatively straightforward. Total area covered by mangroves was determined from the collective mangrove shapes drawn by a built-in utility in the software. Ground truthing, to include field ocular inspections and GPS reference point confirmation, were also conducted.

In order to compare the current extent of mangroves from past data, the only topographic maps (1:50,000 scale) of 1953 and 1988 of the Batan Estuary available from the National Mapping and Resource Information Authority (NAMRIA) of the Philippines were used. These were scanned and loaded onto OziExplorer (ver. 3.95) software, calibrated and geo-coded to UTM coordinate system using actual ground-based points taken with a Garmin eTrex Legend GPS device. Calibrated maps were then imported into GPSMapEdit (ver. 1.0.25) software. Mangrove areas, clearly delineated in the maps, were carefully traced into digital polygons while zooming in to maximize edge accuracy. Individual patches of mangroves were digitized into separate shapes and later combined into a group for area calculation. The total area covered by mangroves was determined using a built-in function of the software. The same method was used to determine the area of culture ponds in 1988 found in the topographic map, while additional pond distribution data in 2000 was obtained from existing municipal records of Altavas, Batan and New Washington (Babaran et al. 2000). To determine the relative impact of aquaculture on mangrove areas, registered ponds outside the original (1953 map) mangrove perimeter were excluded.

2.2.2. Physical water parameters

There were 12 measurement stations – six in the rivers marked as R1 to R6 and another six in the bay/lagoon areas marked as B1 to B6 (Fig. 2-2). Physical water

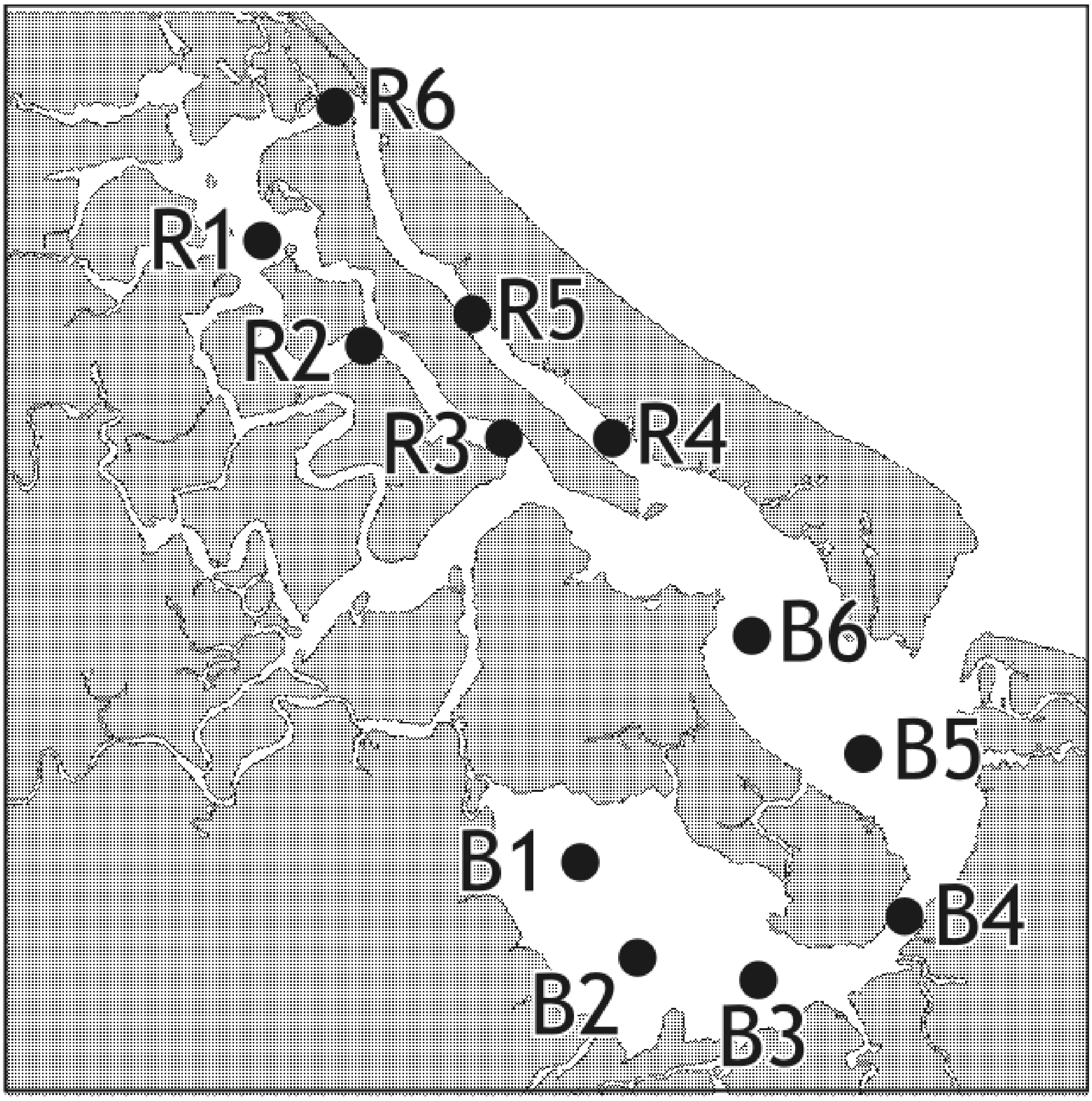

Figure 2-2. Sampling stations for physical water parameters. Six stations in the upper river areas (R1 to R6) and six in the lower bay/lagoon areas (B1 to B6)

quality parameters like temperature, salinity, dissolved oxygen (DO), pH, total dissolved solids (TDS), conductivity, and turbidity were measured using the Horiba U-21XD multi-probe portable meter while water depth was measured using the Norcross Hawkeye DF2200PX portable sounder. Measurements were conducted in October 2006 on a fair weather to avoid external effects of rain and strong winds. Aside from measurements done spatially with the 12 stations, comparisons were also done along the water column. Water surface (50-100 cm from surface) and bottom (50-100 cm from substrate) measurements were also taken to assess the existence of stratification. Temporal changes in water temperature and salinity were also measured in a 24-h period in eight representative stations (4 in the river; 4 in the bay) using the Alec ACT-HR data loggers. These data loggers were deployed at mid water level, automatically recording temperature and salinity levels every 10 minutes.

Determination of differences and similarities within the Batan Estuary was examined using SPSS statistical software with Hierarchical Cluster Analysis applied to the physical water quality data with Squared Euclidian distances and Z-score data standardization.

2.2.3. Water depth change

To estimate the change in water depth from previous decades, a comparison was done between an available 1979 depth sounding data with recent actual depth soundings using a portable Norcross Hawkeye DF2200PX. The 1979 data was taken from a published navigational chart of Batan Estuary by NAMRIA (Port of Batan, 1979 Survey, 2nd Edition. 1:30,000. North Coast of Panay, Philippines Series. Sheet 4413) (Fig. 2-3). This chart was scanned using a flat-bed scanner and calibrated UTM coordinates using actual ground-control points taken on-site with a Garmin eTrex

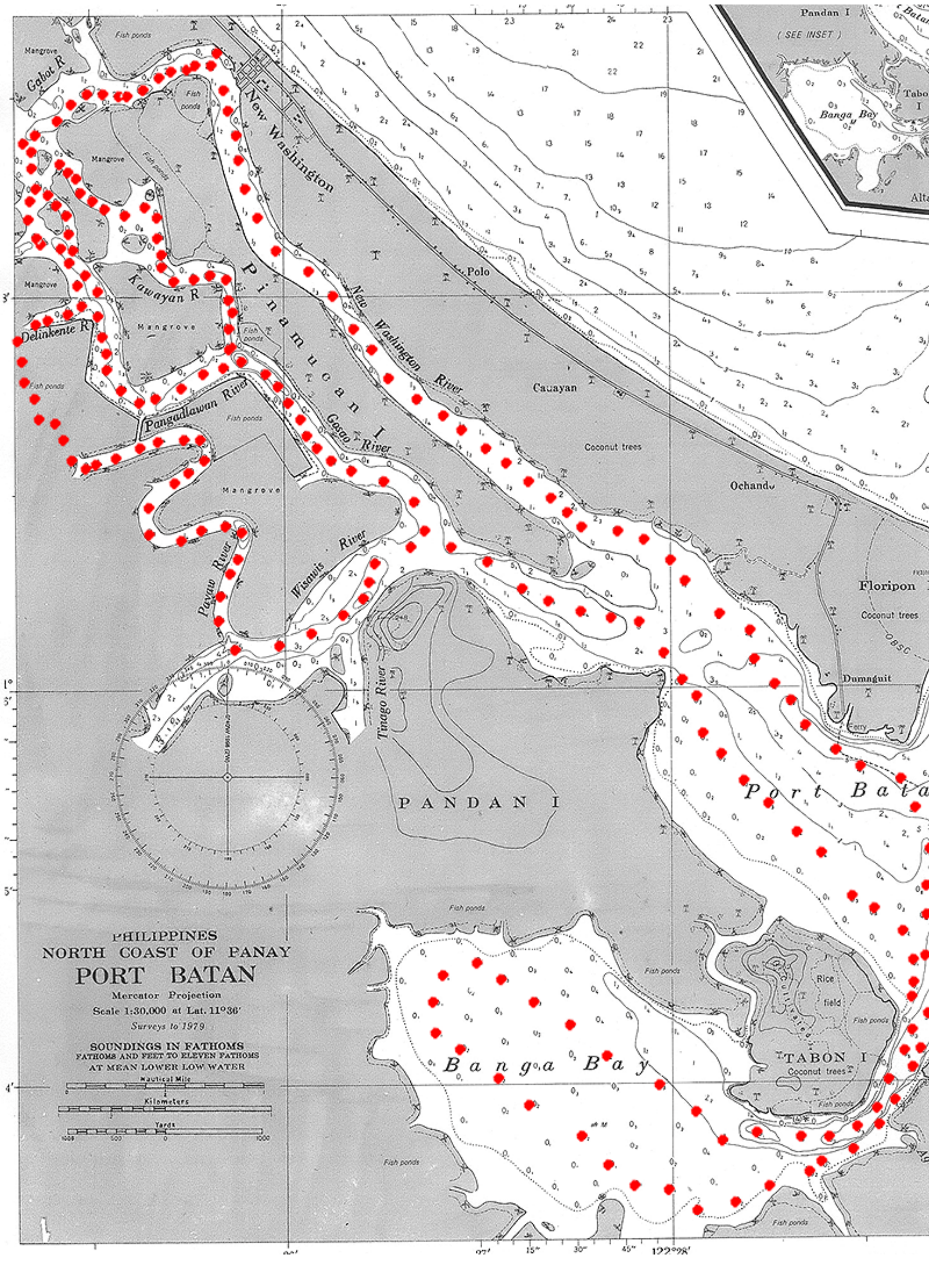

Figure 2-3. Base map with the 1979 depth soundings data superimposed with 204 data points used for depth comparisons.

Legend GPS device. A total of 204 points on the map with known depth were lifted as waypoints to be used as monitoring stations for the present soundings. Uploaded onto the GPS device, specific stations were easily pin-pointed in the field for depth measurement. During the actual field measurement, time and tide levels were carefully considered for each point that was used for depth correction. All the data were plotted and the difference between the 2009 readings and 1979 data were calculated. These were then graphically presented as colored contours automatically generated using Surfer ver. 8 plotting software. Actual latitude and longitude coordinates were used as X and Y axis, respectively, while values of depth difference between 2009 and 1979 data at each of the 204 points were used as Z values in plotting the contours. Although no further quantitative analysis was done, the basic assessments on general depth changes can already be assessed.

2.3. Results and Discussion

2.3.1. Mangroves

Basic data on mangrove cover is very important, especially in the Philippines. The absence of this information alone may lead to inefficient and unsuccessful coastal resource and environmental management, as well as in policy making. As the example in this study show, the currently available maps showing mangrove distribution have huge discrepancies from actual mangrove conditions.

A summary showing the changes, both in mangrove cover and aquaculture ponds, is shown in Table 2-3. Analysis of the 1953 topographic map revealed a total mangrove area in the estuary to be 4,923 ha, showing lush mangrove cover over the whole estuary (Fig. 2-4A). This was reduced to 4,244 ha with 513 ha of ponds in the southeast portion in 1988 (Fig. 2-4B), as analyzed from the topographic map with

Table 2-3. Changes in area covered by mangroves and culture ponds in Batan Estuary, Aklan, central Philippines from 1953 to 2008.

Year	Mangrove area (ha)	Ponds (ha)	Source
1953	4,923	0	NAMRIA topo. map
1988	4,244	513	NAMRIA topo. map
2000	n.d.	4,336	Municipal Fisheries Registry
2008	406	3,747	This study

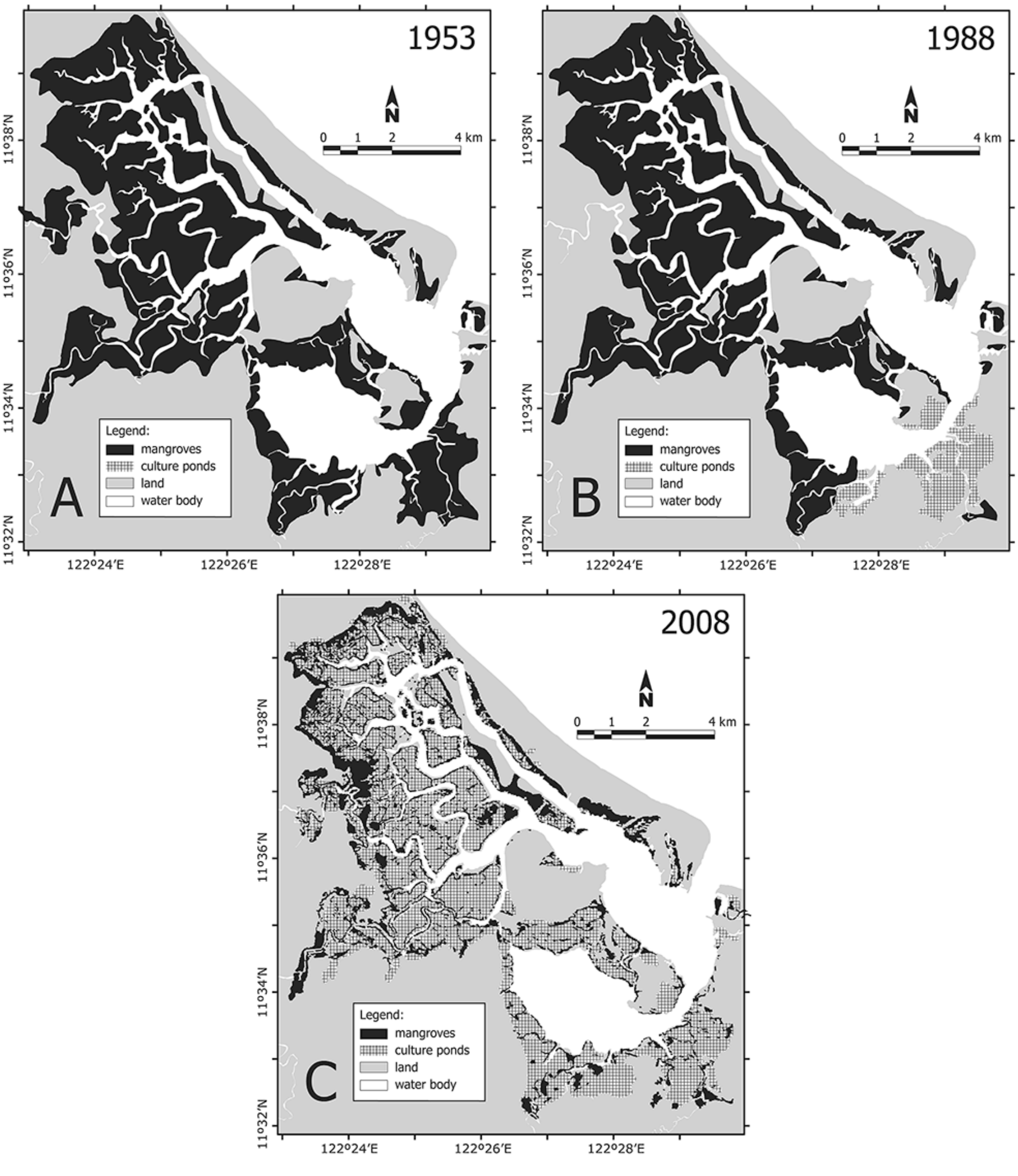

Figure 2-4. Mangrove and aquaculture pond distribution in the Batan Estuary, Aklan Province, central Philippines in (A) 1953, (B) 1988, and (C) 2008.

data of the same year. However, only a total of 409 ha of scattered mangroves were revealed in 2008, most of these are thin strips of replanted *Rhizophora* trees along the dikes of ponds, as confirmed by actual field observation.

Meanwhile, culture ponds expanded to cover a total area of 3,747 ha in 2008, increased by 86% from 1988, while virtually replacing 76% of the original mangroves in 1953 (Fig. 2-4C). The collective Municipal Fisheries Registry of the three municipalities around the estuary showed an even wider area of 4,336 ha of aquaculture ponds in 2000 (Table 2-3).

Based on a digital map from NAMRIA, Babaran et al. (2000) showed that this estuary had an area of about 4,800 ha in 1953. In the current study, however, a much detailed estimate of 4,923 ha was determined (Table 2-3, Figure 2-4C). As shrimp culture technology was introduced, aquaculture farms were also constructed in the Batan Estuary totaling 513 ha (8% of the original 1953 mangroves) concentrated in the south-eastern part by 1988 (Figure 2-4B). In the same year, mangroves decreased to 4,244 ha, as analyzed from the topographic map (NAMRIA Topographic Map 3424-II, 1996) with 1988 source data. Results also showed that about 165 ha of mangroves were lost but not directly converted to ponds. This unaccounted loss can be attributed to areas of pond dikes and canals, as well as sites for hatcheries and probable conversion into settlements and other uses by the local communities. Some local residents claim, however, that much wider expanse of fish and shrimp ponds was already constructed since the late 1970s, suggesting inaccuracy of the 1988 topographic maps. Although there are no published evidence on this claim, LandSat MSS images of 1976 (GLCF 2009) show extensive pond structure all throughout the estuary, but no further analysis was made.

Pond construction actually started before the 1950s in the country but the boom in the shrimp industry in the 1980s sped up the rate to about 4,700 ha yr^{-1} (Primavera 2000). This is very evident in the Batan Estuary where a total of 4,336 ha of ponds were registered in the year 2000, converting 88% of the original mangrove-covered area of 1953. Our analysis of a recent 2008 aerial photo revealed a slightly lower value of 3,747 ha for ponds. The discrepancy of 589 ha ponds between 2000 and 2008 can be associated with some abandoned ponds especially in the northern rivers where dikes were damaged and opened by floods and storms. This is shown as original landmass in Fig. 2-4C but no ponds or mangroves are specified. These were consequently excluded in the classification of culture ponds in our resulting map of 2008. In this latter year, the total mangrove area was estimated to be only 406 ha.

The main concern in this paper is that the currently available map has the source data of 1988 showing total mangrove area of 4,244 ha (Fig. 2-4B), as determined above. However, verbal testimony and initial results from 1976 satellite images show vast distribution of ponds and lesser mangrove cover even before 1980. More realistically, present mangroves in the Batan Estuary are revealed to occupy only scattered patches totaling 406 ha. This is close to the initial estimate of Altamirano (2007) of about 300 ha. In addition, these mangroves are not remnants of the original forests decades ago, but are secondary growths that form narrow fringes along the creeks and river banks (Ikejima et al. 2006). Also, only thin 2-3 m strips of replanted *Rhizophora* species were planted primarily to protect dikes of ponds.

2.3.2. Physical water parameters

The summary of the results of physical water parameters for the 12 stations in the Batan Estuary are presented in Table 2-4. Measurements for surface and bottom

Table 2-4. Physical water quality (surface and bottom) of the 12 stations in the Batan Estuary in October, 2006.

	Depth (m)	Temp (ºC)		Salinity		DO ($mg \cdot L^{-1}$)		TDS ($g \cdot L^{-1}$)		pH		Turb($mg \cdot L^{-1}$)	
		Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot
<u>River Stations</u>													
R1	4.6	30.2	29.8	31.0	31.0	5.9	6.1	29.0	29.0	7.7	7.6	10.0	16.0
R2	4.2	30.4	29.7	32.0	33.0	5.6	5.9	29.0	30.0	7.7	7.7	7.0	10.0
R3	2.3	29.3	29.3	31.0	31.0	5.5	5.2	29.0	29.0	7.6	7.5	11.0	15.0
R4	2.1	29.2	29.2	32.0	32.0	4.3	4.3	30.0	30.0	7.5	7.5	9.0	12.0
R5	3.7	29.4	29.3	31.0	31.0	4.8	4.3	29.0	29.0	7.6	7.5	9.0	11.0
R6	5.9	29.3	29.2	29.0	29.0	5.1	4.4	28.0	27.0	7.5	7.5	9.0	13.0
Mean	**3.8**	**29.6**	**29.4**	**31.0**	**31.2**	**5.2**	**5.0**	**29.0**	**29.0**	**7.6**	**7.5**	**9.2**	**12.8**
Std.Error	±0.59	±0.21	±0.11	±0.45	±0.54	±0.24	±0.34	±0.26	±0.45	±0.03	±0.03	±0.54	±0.95
<u>Bay Stations</u>													
B1	1.3	28.7	28.7	32.0	32.0	5.2	5.4	30.0	30.0	7.7	7.7	25.0	33.0
B2	2.3	29.2	29.1	34.0	34.0	6.0	5.9	31.0	31.0	7.9	7.8	22.0	14.0
B3	3.2	28.9	29.0	33.0	33.0	5.6	5.7	30.0	30.0	7.8	7.8	18.0	19.0
B4	1.7	28.7	28.6	32.0	32.0	5.7	5.6	29.0	30.0	7.7	7.7	12.0	21.0
B5	1.5	29.1	29.1	34.0	34.0	5.8	5.8	31.0	31.0	7.8	7.9	5.0	8.0
B6	3.0	29.3	29.4	32.0	32.0	5.1	5.1	19.0	30.0	7.8	7.8	4.0	7.0
Mean	**2.2**	**29.0**	**29.0**	**32.8**	**32.8**	**5.6**	**5.6**	**28.3**	**30.3**	**7.8**	**7.8**	**14.3**	**17.0**
Std.Error	±0.33	±0.10	±0.12	±0.40	±0.40	±0.14	±0.12	±1.89	±0.21	±0.02	±0.03	±3.58	±3.94

water for most parameters were almost the same except for turbidity with a difference of about 3 mg·L^{-1}. SPSS Hierarchical Cluster Analysis showed differences and similarities between stations in a form of a dendrogram (Figure 2-5). At similarity distance of 18, four clusters were evident and subjectively named as (1) Lagatik River, (2) Pinamucan River, (3) Bay Area, and (4) Mixing Area. The cluster boundaries were arbitrarily marked on the map shown in Figure 3-3. The 24-H monitoring for temperature revealed a trend ranging from 29.5-30.3 ºC for the River stations and 28.4-29.7 ºC for the Bay stations. Salinity ranged from 26.6-30.2 ppt for the River stations and 29.9-32.3 ppt for the Bay stations.

Surface and bottom measurements for all parameters except turbidity were basically the same (Table 2-4). This means that the water column of the whole estuary is well mixed. This can be attributed to the relatively shallow average depth of 3.8 m and 2.2 m for the rivers and the bay area, respectively. Bottom measurements for turbidity on the other hand, were higher by about 3 mg L^{-1} than the surface. Because of constant water movement, substrate materials are always disturbed producing greater turbidity near the bottom especially in areas with high silt deposits.

The hydrographic properties on the Batan Estuary is influenced by many factors like freshwater inputs from rivers, seawater intrusion, oceanic tides, evaporation, wind, and the physical size and shape of the water body. These factors affects different parts of the estuary in relatively different degrees, hence there are possible differences or similarities between portions of the Batan Estuary. With the cluster analysis, four general areas were determined (*Lagatik* River, *Pinamucan* River, Bay Area, and Mixing Area) within the Batan Estuary (Fig. 2-5).

Temporal assessment of water temperature and salinity with 24-h monitoring showed a clear trend with difference between the river and the bay sites (Fig. 2-6).

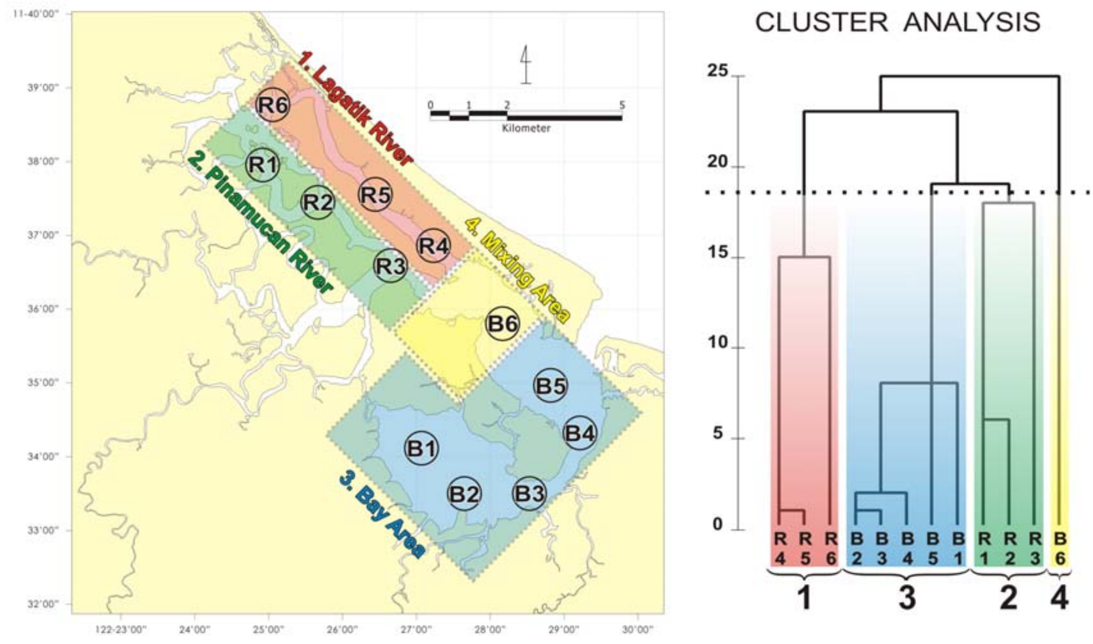

Figure 2-5. (left) Twelve stations (R1-R6 in the rivers and B1-B6 in the bays) used to monitor physical water parameters (October 2006) and the respective groupings; (right) dendrogram from SPSS Cluster Analysis revealing four groups.

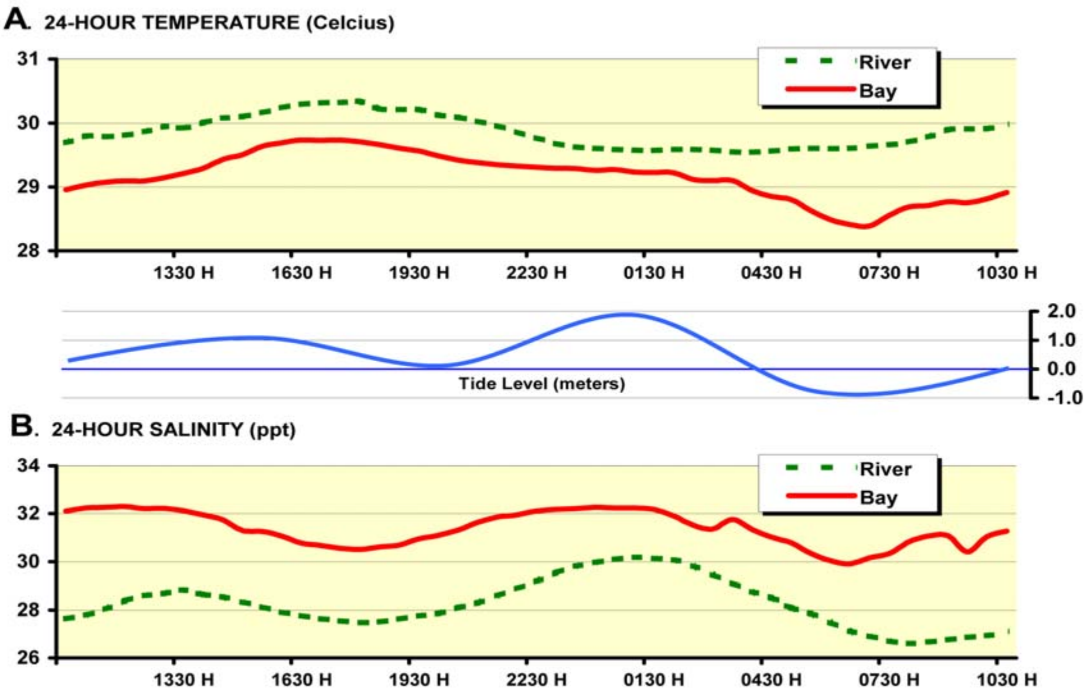

Figure 2-6. (A) Average 24-h temperature (ºC) readings (n=4) for the River and the Bay areas; (B) Average 24-h salinity (ppt) readings (n=4) for the River and the Bay areas in October 2006; Middle chart showing tide level (m) reference.

Temperature was relatively higher by 0.5-1°C in the rivers than in the bay areas. The narrower channels in the rivers correspond to lesser volume of water compared to the wide bays, hence the faster warming of the water from the sun's heat. In terms of salinity, the bay area was higher by 2-4 ppt than the rivers. The proximity of the bays to the seawater source and constant flow of freshwater from the upper creeks to the rivers explain this difference. Tide level showed no association with water temperature where the peak occurred at about 4:00–6:00 PM and the lowest during 3:00–4:00 AM. Water salinity showed strong coincidence with the tide when the highest salinity occurred during high tide and decreased as the tide receded. This clearly shows the instant effect of flood tide when sea water enters the estuary. Figure 2-6B also shows that the river data curve is slightly skewed when compared to the bay data curve. This suggests a minimal lag of a few minutes for the sea water to enter the rivers.

2.3.3. Water depth

Results show that the whole Batan Estuary has generally become shallower at present compared to 30 years ago. Graphically plotting the differences in depth between 1979 and 2009 revealed areas of intense sediment deposition, as well as areas with substrate erosion (Fig. 2-7). These interpolated contours were automatically generated with the use of the software called Surfer ver. 8 from the data collected. Initial look at Figure 2-7 shows a characteristically reddish hue for the water body, indicating a general shoaling (substrate accretion) effect. However, some areas also show some degree of deepening water, especially near the mouth of Batan Bay. This can be explained by the occasional dredging done in this area as required by the operations of a port nearby, called Port of Dumaguit. Other areas that show bluish

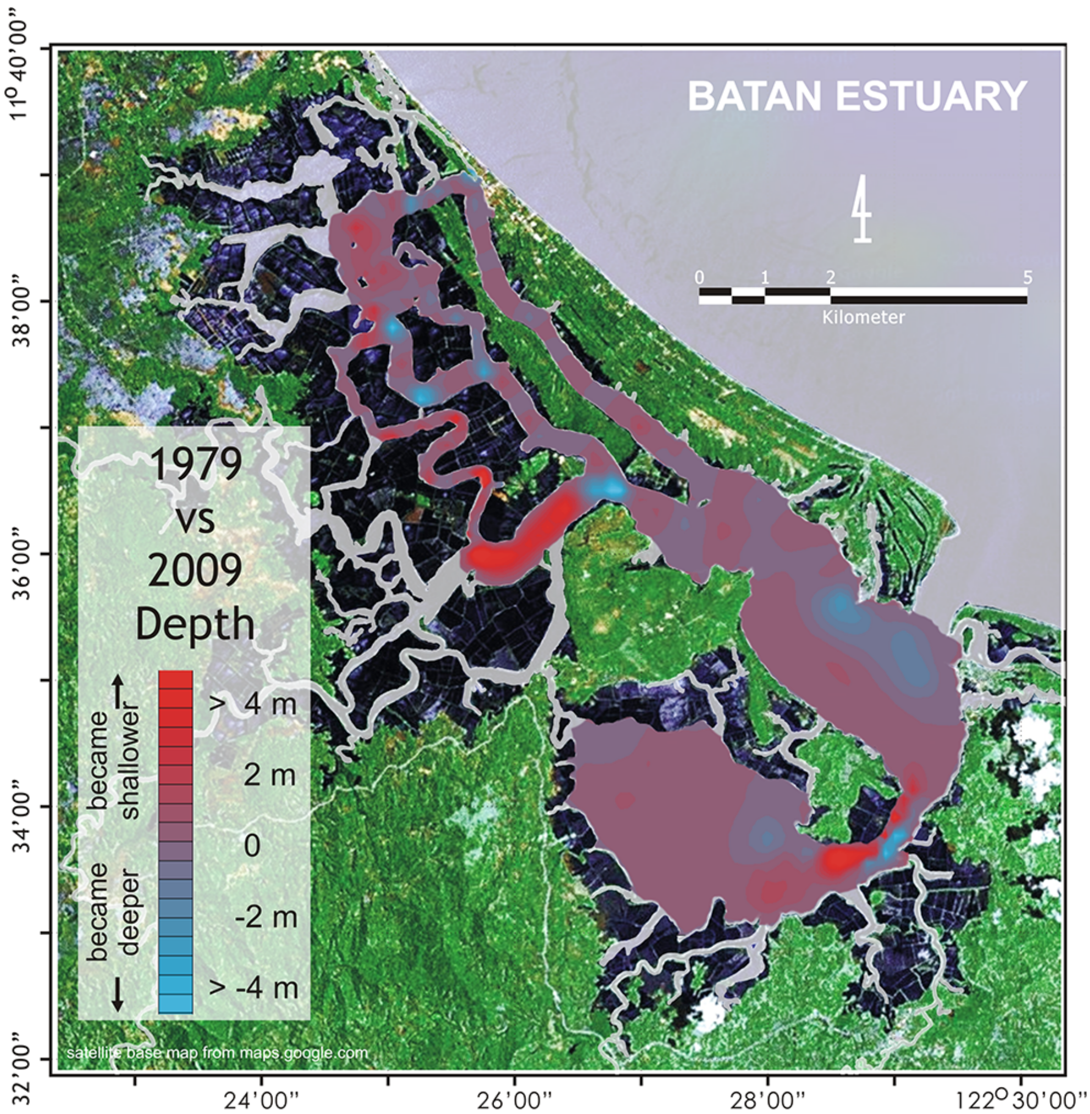

Figure 2-7. Differences in water depth between 1979 (Nautical Chart) and recent 2009 depth soundings (n=204).

color indicating a deeper water compared with that of 1979 are river bends and junctions. Here, water flow is much more dynamic and greatly increased especially during floods, scouring sediments and depositing in adjacent beds.

Data also showed that 64% of 204 stations recorded shoaling at an average of 1.5±0.2 m after 30 years (from 1979 to 2009). This also translates to a mean sedimentation of about 5.3 cm yr^{-1}. This rate is still very conservative compared to a previous estimate of 17.5 cm yr^{-1} (Rodriguez 2001).

It can also be deduced from the results that substrate materials from the upper river were eroded and deposited along the lower rivers and bays which clearly suggest the effects of siltation over the years. Although a thorough analysis on silt transport and deposition were not conducted, the current results already support the claim of the people that the Batan Estuary is generally getting shallower.

2.4. Chapter Summary

Some decades ago, the Batan Estuary was considered to be a very productive fishing ground with healthy waters that support an abundance of aquatic species and lush mangrove forests lining the banks extending inland up to the edges of the tidal shore, acting as ideal habitats for birds, wild animals and even smaller crustaceans, molluscs and insects. As societies change, the natural environment is also modified. The increase in population brought about more demand for food and thus more fishing pressure. Although population increase in the Batan Estuary slowed down recently to about 10% per decade, compared to 22% from 1950 to 1960, the overexploitation and destruction of the estuary did not seem to lessen.

The development of aquaculture technology in the 1970s has contributed a dramatic change in the area. Almost all (92%) of the mangroves in the Batan Estuary have been indiscriminately cleared out since the 1950s mostly for the construction of aquaculture farms and ponds. Although some efforts were made to replant mangroves, these were only seen to be mostly thin strips of *Rhizophora* trees lining dikes for protection against wave action, storms and flood.

The destruction of mangroves has also devoid the estuary with buffer zones from typhoons, pollution, erosion and siltation. Deposition of additional substrate in the estuarine rivers and lagoons was observed by the fishers themselves, declaring that the rivers and bays were becoming shallower. Because of the apparent denudation of the upland mountains and the clearing of mangroves, erosion of sediments became unrestricted. In the analysis of water depth change between 1979 and 2009, a deposition rate of 5.3 cm yr^{-1} was calculated. This is even much more conservative than the previous estimate of 17.5 cm yr^{-1} (Rodriguez 2001).

Although the negative effects of mangrove destruction and water substrate accretion, the present physical water quality in the estuary still remained within natural levels, like dissolved oxygen, pH, salinity and temperature. This means that the estuary can still be ecologically fit for fish and shrimps to survive. However, these parameters can also be affected by forces such as during typhoons and floods. On the other hand, bio-chemical analyses of the site were not done in this study, and may also show different conclusions. Also, other factors may still be affecting water quality like the intense crowding of fishing structures, which will be discussed in the next chapter.

CHAPTER 3

FISHERIES IN BATAN ESTUARY

CHAPTER 3

FISHERIES IN BATAN ESTUARY

3.1. Introduction

3.1.1. Philippine fisheries

In the Philippines, being an archipelago with vast continental shelf area of 184,600 km^2 and 17,460 km of total coastline (BFAR 2003), fisheries is considered as a major industry and livelihood. This importance is evident in the fact that the Philippines ranked 11th among the top fish producing countries in the world in 2001 (FAO 2003) and 6th in 2004 (BFAR 2006). In the national level, fisheries industry contributed 2.2% (PhP129.8 billion) and 4.3% (PhP54 billion) in the country's total GDP in 2006 using current and constant prices, respectively (BFAR 2006).

The fisheries industry in the Philippines has three sectors: aquaculture, commercial fisheries, and municipal fisheries. According to the Philippine Fisheries Code (1998), aquaculture is any fishery operation involving all forms of culturing fish and other fishery species in fresh, brackish and marine waters. Commercial fisheries is taking of any fishery species by passive or active gear for trade, business or profit beyond subsistence or sports fishing done in open waters more than 15 km from the shore and utilizing boats of more than 3 gross tons; while, municipal fisheries is any capture fishing activity requiring no boat or that which utilizes boats of 3 gross tons or less in inland and coastal rivers, lakes, bays and marine waters within 15 km from the municipal coastlines. Municipal fisheries is also referred to as artisanal, small-scale or traditional fisheries (Lim et al. 1995). Aquaculture produces more than capture fisheries and showed highly positive growth from 1999, 2003 and 2006, while both capture sectors has been steady and sometimes even decreasing (Table 3-1).

Table 3-1. Contribution of the three fisheries sectors in production and employment in the Philippines in 1999, 2003 and 2006.

	PRODUCTION						EMPLOYMENT					
	1999		2003		2006		1999		2003		2006	
	Quantity[a] (Value)[b]	%	Quantity[a] (Value)[b]	%	Quantity[a] (Value)[b]	%	People	%	People	%	People	%
Aquaculture	978 (26.8)	34 (30)	1,454 (37.2)	40 (31)	2,092 (55.6)	47 (34)	74,537	9	258,480	26	226,195	14
Commercial	946 (32.2)	33 (36)	1,110 (42.0)	31 (35)	1,080 (48.5)	25 (30)	357,984	44	56,715	6	16,497	1
Municipal	944 (30.8)	33 (34)	1,055 (40.7)	29 (34)	1,235 (59.1)	28 (36)	374,408	46	675,677	68	1,371,676	85
Total	2,868 (89.8)		3,619 (119.9)		4,408 (163.2)		806,929		990,872		1,614,368	

[a] Production quantity in thousand metric tons (000 MT), [b] Values in Million Philippine Peso (Ph.₱) [Ph.₱ 1 ≈ US$ 0.02 ≈ JP¥ 2]

Source: BFAR 2000; BFAR 2003; BFAR 2006

However, in a more social scenario, municipal fisheries provided more impact in terms of employment than the other sectors. Table 3-1 also shows an 80% increase of employment in the municipal sector from 1999 (374,408) to 2003 (675,677) and an even greater increase of 103% after 3 more years in 2006 (1,371,676). This is because of, in part, to the increasing population in coastal areas and the lack of other alternative livelihood to fishing in the rural coastal villages. In 2001, the total population of the Philippines reached 76 million and it is estimated that 55% (41.8 M) are residing in coastal areas (Rivera et al. 2002). Of these coastal dwellers, 68% are involved in municipal fisheries that are directly or indirectly dependent on fishery resources.

In the Batan Estuary, based on the 2007 Municipal Fisheries Profile of New Washington as a representative, 58% (24,100) of the total population (41,000) were associated with fishing. In terms of households, 70% (5,850) of 8,354 reside directly along the coasts. Of these, 73% (4,251) were involved in municipal or artisanal capture fisheries while 14% were into aquaculture, 5% employed in commercial fishing, and the rest work in post-harvest fish processing. A study by Babaran et al. (2000) revealed that 86% of about PhP (Philippine Pesos) 40,000 (≈US$ 750) annual family income came from fisheries-related activities in 1999.

The increase in population especially in the rural coastal areas, coupled with the preference for municipal fisheries, consequently impose greater pressure on coastal ecosystems that threatens not only the coastal resources but also the lives of local fishing communities.

3.1.2. Inshore fisheries in Batan Estuary

Municipal or artisanal inshore fishing in the Batan Estuary is multi-species. It has been shown that penaeid shrimps were consistently the top commodity in terms of catch frequency, dominance and weight (Table 3-2). Ingles et al. (1992) also noted that shrimp fishery is the most important livelihood in the area and that most gears were designed for shrimp capture. The most obvious gears used inside the estuary are stationary structures built from bamboos and nets. These include fish corrals (locally called *taba*, *tigbakol*, or *tulis*), lift nets (*bintahan*, *batak batak*), and filter nets (*saluran*, *tangab*) (Fig. 3-1). Active gears are also being used like the common hook and line, gill nets, crab and shrimp traps, seine nets, barrier nets, skimming nets and spears (Fig. 3-2). Structures for open aquaculture like mussel/oysters stakes and fish cages are also scattered along river banks. Because of the lack of efficient fisheries management guidelines and weak law enforcement, however, construction and use of these gears remain under-regulated. Some fishers even engage in illegal fishing like the use of fine-meshed nets (Añasco and Babaran 2001). There is also no defined zoning of gears that commonly caused conflicts among fishers (author's observation).

3.1.3. Objectives

This chapter describes the status and trend of inshore fisheries within the Batan Estuary. Focus is especially given on shrimps being the major commodity in the area (Ingles et al. 1992). Specifically, this chapter aims to present the following:

1) Fishers of the Batan Estuary: population, demography, and composition

2) Fisheries problems in the Batan Estuary

3) Fishing gears and their distribution

4) Daily fisheries production and trend in catch-per-unit-effort (CPUE)

Table 3-2. Top 10 most dominant inshore fishery resources (based on relative abundance) captured by stationary fishing gears in the Batan Estuary in 1999 (after Babaran et al. 2000).

Species	Relative Abundance Index (%)	Family	English Name	Local Name
1. *Metapenaeus ensis*	16.9	Penaeidae	Greasyback shrimp	batud
2. *Stolephorus commersonii*	11.3	Engraulidae	Anchovy	bolinao
3. *Siganus* sp.	6.4	Siganidae	spinefoot	mobead
4. *Gronovichthys* sp.	6.0	Apogonidae	Cardinal fish	bakagan
5. *Alepes macrurus*	4.3	Carangidae	Herring scad	mangudlong
6. *Penaeus merguiensis*	3.8	Penaeidae	Banana shrimp	puti-an
7. *Apogon* sp.	3.7	Apogonidae	Cardinal fish	bakagan
8. *Leiognathus splendens*	3.6	Leiognathidae	Splendid ponyfish	sapsap
9. *Sardinella longiceps*	3.2	Clupeidae	sardine	lap-lap
10. *Oxyurichthys* sp.	3.1	Gobiidae	Goby	tanga

fish corral
(*taba*, *tigbakol, tulis*)

lift net
(*bintahan, batak-batak*)

filter net
(*tangab, saluran*)

fish cage
(cage)

fish shelter
(*gango*)

oyster/mussel stakes
(*talabahan, tahongan*)

Figure 3-1. Common stationary fishing structures being used in the Batan Estuary.

gill net
(*pantehan*)

hook and line
(*panonit*)

shrimp trap
(*timing*)

crab trap
(*bintol*)

barrier net
(*sagpang*)

fish spear
(*pamana*)

Figure 3-2. Some forms of active fishing being used in the Batan Estuary.

3.2. Methods

3.2.1. Interviews

Two separate interview surveys were conducted in 2006 and 2009. In the former, open-ended questions in the local language (Akeanon and Tagalog) were asked among fishers, detailing (1) basic demographic data, (2) fishing methods and practices, (3) past and present fishing catch rates, observations, and (4) their perception of existing problems in the area. Individual responses were recorded in prepared forms. About 200 random fishers from around the estuary were questioned but only 105 complete responses were used in this study. Answers requiring word inputs were translated to the closest English meaning for purposes of presentation.

In 2009, a more focused interview survey were conducted in the Municipality of New Washington, covering five barangays (or villages) whose fishers only directly utilize the rivers of the Batan Estuary. A more detailed questionnaire was used covering the same concerns as the former survey above. This was conducted with five trained enumerators using the local language (Akeanon and Tagalog). A total of 107 respondents were randomly interviewed.

3.2.2. Stationary fishing gears survey

In October 2006, a survey of stationary fishing gears was conducted in the waters of Batan Estuary. To determine the actual count and specific location of each gear, a small outrigger motorboat was used to navigate through the scattered fishing gears and marked using a Garmin e-Trex Legend GPS receiver. Manual recording of positions and gear types was also made on a scaled map. In some areas where boat entry was limited, ocular estimates were done as to the relative positions of the gears and noted on the printed map. Inaccessible minor creeks were not included in the survey. Five main fishing structure types were identified and mapped, namely: fish corrals, lift nets, filter nets, fish cages and, oyster/mussel stakes. Because of difficulty in defining individual units of oyster/mussel stakes, these were only mapped but not included in the total count. Collected data were compared with available information from other studies in 1991 (Ingles et al. 1992) and 1999 (Babaran et al. 2000).

3.2.3 Actual catch data

Although there were various fishing gears being used in the estuary, the fish corral was chosen for monitoring catch because of its dominance and widespread distribution. In addition, Babaran et al. (2000) also pointed out that fish corrals capture the most number of species from among the gears used in the Batan Estuary. Fish corrals are constructed using bamboo stakes and nets. The simple structure of a fish corral include a square *bunu-an* or catchment bag which is about 3 m at each side and about 2 to 4 meters high, depending on location and water depth (Fig. 3-3). Leading away from the *bunu-an* is a pair of wings, called *taktakon*, spreading at about 50-70 degrees and reaching 10-20 m long. These are usually operated by setting down the *bunu-an* in the afternoon and lifted for harvest in the next morning. Peak operations occur roughly twice a month during spring tides, although fishers commonly operate almost every day. A kerosene lamp is also placed inside the catchment bag just above the water to act as an aggregating device.

Six stations scattered in the upper rivers and another six in the lower lagoons were monitored fortnightly (on peak fishing) from June to November 2006. Sampling was done in the morning when fishers harvest their gears between 0400–0700 H after an average of 12 hours operation (catchment bag lowered). Total catch from every station was measured and a random sample weighed and purchased from the fisher.

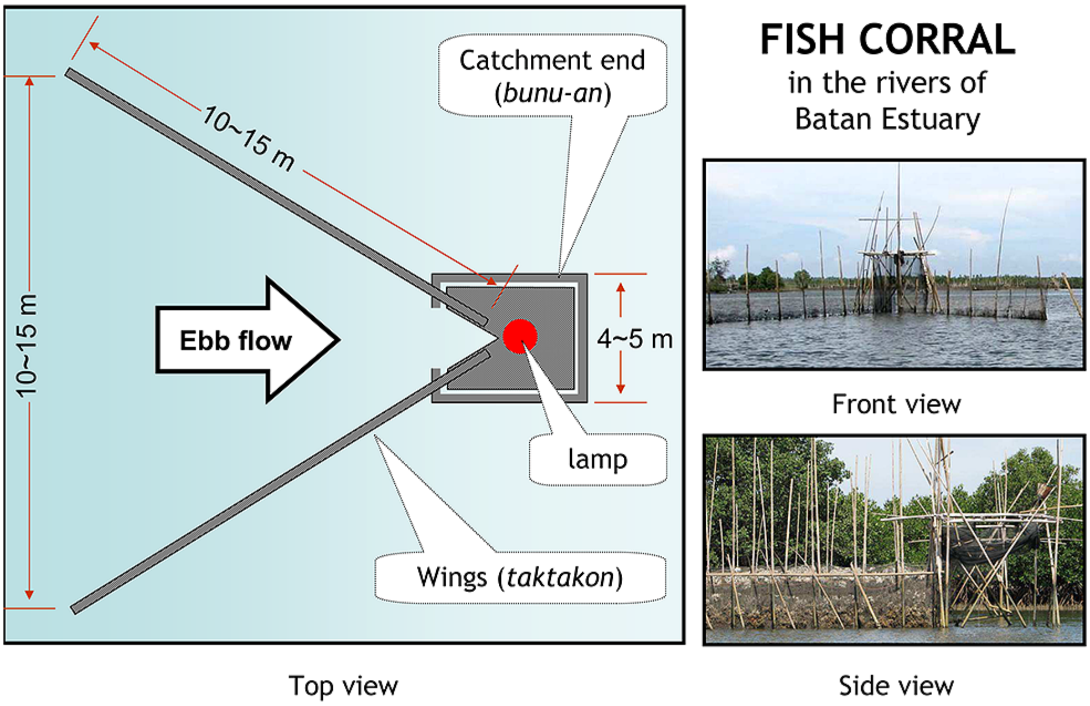

Figure 3-3. Structure of a typical fish corral operated in the rivers of Batan Estuary.

This sample was then generally classified into fish, crab and shrimp. Further classification of fish and crabs were not done because the focus was set on shrimps being the major commodity. Moreover, a more detailed list of species caught by different gears was already presented in the literature (Ingles et al. 1992; Babaran et al. 2000). On the other hand, shrimps were further classified into sizes and major species like *Metapenaeus ensis*, *Penaeus merguiensis*, and *Penaeus monodon*. Other less important shrimp species were also found in small quantities, hence were generally classified as “others”. Sample weight of fish, crab and shrimps were adjusted relative to the total catch weight and were used in the calculations and comparisons among stations. Prior analysis, data were transformed to log (x+1) to improve homogeneity of variances (Zar 1999). Data were tested using Analysis of Variance (ANOVA) and Multiple Range Test (Duncan’s Test) with significance set at $P<0.05$. Finally, average catch-per-unit-effort or CPUE was determined and compared with data from previous studies to establish trends.

3.3. Results and Discussion

3.3.1. Fishers of Batan Estuary

All 105 respondents in the 2006 survey were either of the parents of their respective households with an age range of 31 to 76 years old. Average household size was 8, which is common in coastal communities in the Philippines (Lim et al. 1995; Babaran et al. 2000). However, households with 8-9 children were also common. Meanwhile, the survey in 2009 revealed much more detailed information on the composition of fishers within the estuary. For example, the fishing member in all of 107 participant households was male, commonly the father of the family. Majority of them are between 40 – 50 years old (Fig. 3-4) and mostly have 10 to 20 years fishing experience in the estuary (Fig. 3-5). In addition, 92% of them are full-time fishing with no other forms of employment.

One fishing household usually (84%) operates only one type of fishing gear and majority of them (70%) use 2 to 4 units of fish corrals. Fishing operations, even for fish corrals, are mostly done individually, where 72% go out to fish alone, while some fishers (18%) also get assistance from another family member. This is because most fishing gears only require a single person to operate, except for example, the gill net that requires two. The location of the gears is varied, some are only a few meters from the residence of the fisher and some can be a kilometer away. Most fishing gears, whether stationary or active, require a boat for access. Small outrigger paddle boats are very common means of transport where 76% of the participant households own at least one. However, 30% owns a motorized boat, especially those whose fishing gears are farther away or for those who transact business, like fish trade, directly to the municipal market.

Of all the respondent households, 60% have no other forms of livelihood, while the rest engage in some business like oyster culture, animal husbandry, managing a small grocery store, or fish trading. Of all the alternative sources of income other than artisanal capture fishing, oyster culture was mostly preferred (40%). This suggests that the communities in the Batan Estuary are mostly dependent on aquatic resources that the estuary provides, whether through basic capture fishing or some form of aquaculture.

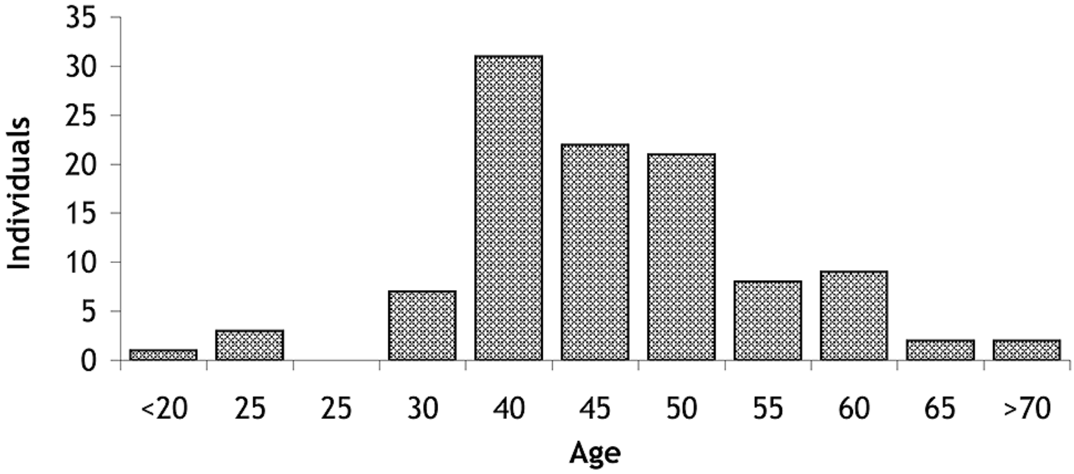

Figure 3-4. Age distribution among fishers in the Batan Estuary (2009 survey, n=107)

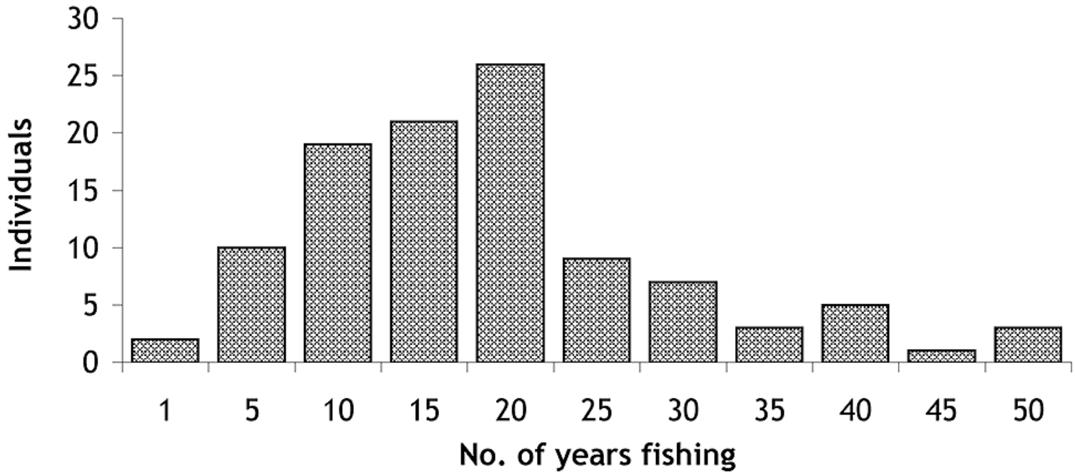

Figure 3-5. Distribution of fishing experiences among fishers in the Batan Estuary (2009 survey, n=107)

3.3.2. People's perception

Results from the first survey showed that fish and shrimps were abundantly available in 1970s, reaching up to 24 kg d^{-1} (Fig. 3-6). This decreased roughly by half in the succeeding decade then further reduced to only 5 kg d^{-1} in 2000. It also shows that the high-priced and preferred tiger shrimp *Penaeus monodon* declined from about 6.0 kg d^{-1} in 1970, 2.8 kg d^{-1} in 1980, and to only 0.5 kg d^{-1} in 2000. This was also supported by the second survey showing that daily catch during the 1990s were around 6 to 10 kg, some even reaching 30 kg (Fig 3-7). However, most respondents only claim to catch about 2 kg per day at present. Although these values were not produced from actual catch measurements, the personal experiences by the fishers themselves cannot be totally dismissed.

Aside from the declining trend in catch and income, respondents also indicated other concerns and problems about the estuary (Table 3-3). They observed that water depth has been becoming shallower as a result of siltation in the rivers and lagoons. Respondents also testified for the rapid mangrove conversion to ponds. Most of them remembered wide lush mangrove vegetation in the 70s and that only very sparse mangroves remain at present. People also mentioned possible pollution and chemicals from aquaculture ponds and agriculture farms that may have been the cause of fish and crustacean kills especially in the months of November to January.

Analysis of responses by fishers on existing concerns revealed that the most regarded problem was having a meagre income caused by poor catch (41% of respondents). They often have more expenses than they actually gain from fishing. Average daily sales of PhP 50-60 (about US$1.5) from shrimps, for example, is only equivalent to a litre of gasoline for boat operations.

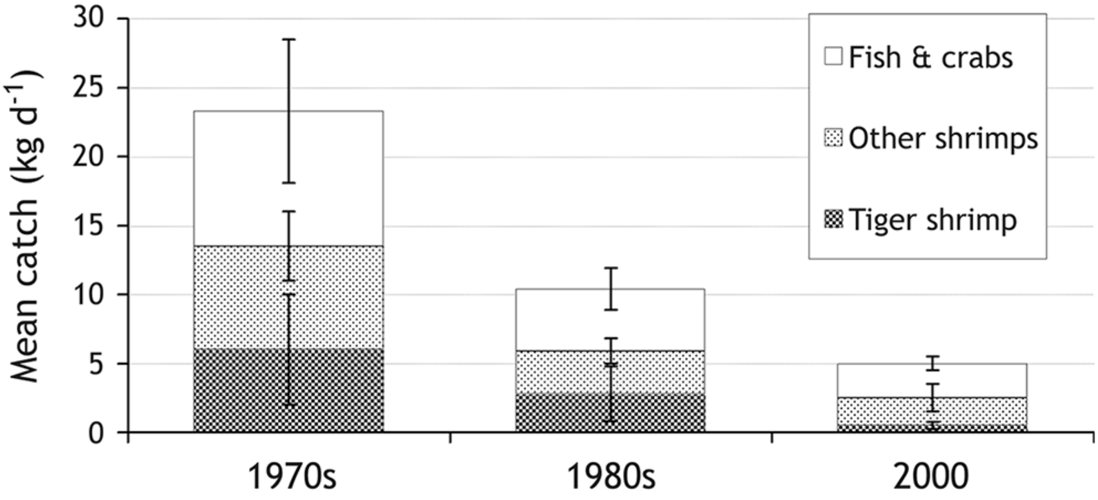

Figure 3-6. Daily mean catch within in the Batan Estuary in 1970, 1980, and 2000 based on interview survey among fishers (2006, n=105).

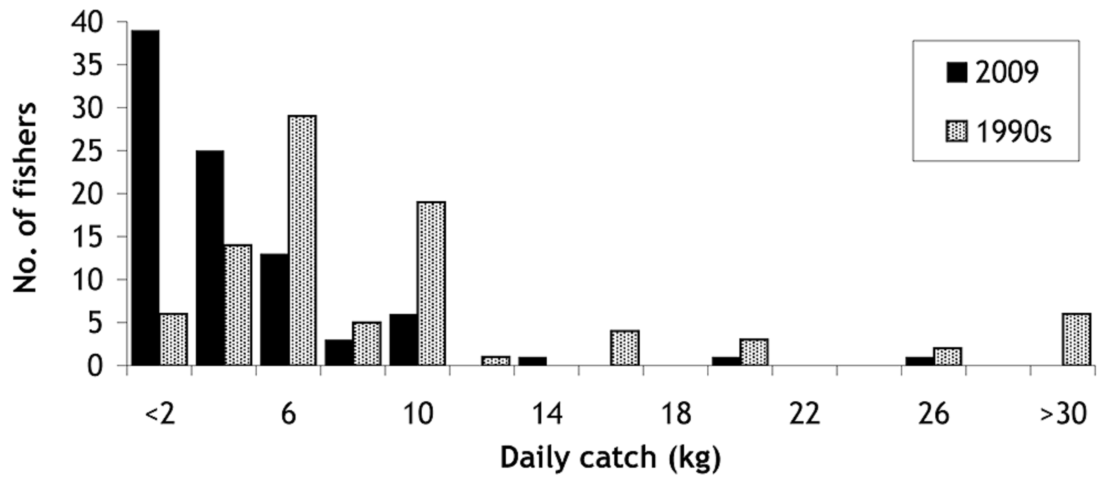

Figure 3-7. Daily total catch within the Batan Estuary per fisher in 1990 and 2009, based on interview survey among fishers (2009, n=107)

Table 3-3. Top 10 problems perceived by fishers in the Batan Estuary in 2006 (ranked and translated from interviews, n=105)

Problems	Responses (%)
1. Low catch, low income	41
2. Garbage, water pollution, chemicals	37
3. Shoaling of rivers and lagoons	24
4. Over-crowded fishing gears, less stocks	19
5. Illegal fishing (fine mesh, etc.)	19
6. Flooding and fish kills	16
7. More fishponds, less mangroves	6
8. Improper implementation of laws	6
9. No alternative livelihood	5
10. Theft of catch and gears	3

Garbage and water pollution ranked second (37%), while concerns about the shoaling of rivers and lagoons came third (24%). Fishers themselves admitted the existence of over-crowded fishing gears (19%) and the use of illegal forms of fishing (19%) like using small-meshed nets and diving with the aid of air compressors. Other problems like flooding during heavy rains, mangrove conversion to ponds, occasional crustacean kills, weak law enforcement, and lack of alternative livelihood, were also clearly noted by the respondents. These results show that the local communities were well aware of the degrading status of the estuary and the threats they are facing based on personal experiences alone.

3.3.3. Fixed fishing gears

It was observed that various fishing gears, both active and passive, are being used in the Batan Estuary. However, the most visible were stationary structures like fish corrals, lift nets and filter nets. Oyster/mussel stakes as well as fish cages for aquaculture were also proliferating in the area. Considering only the major fixed gears mentioned above, Ingles et al. (1992) counted 426 (except fish cages) stationary fishing gears around Batan Estuary in 1991, while Babaran et al. (2000) mapped 2,077 gears in 1999 (Table 3-4). These values dictate an increase of more than 450% in nine years. However, this direct comparison cannot be readily accepted because of possible discrepancies between the two surveys in terms of objectives and survey methods. Ultimately however, the fact of increased fishing pressure in the estuary is clearly illustrated. This multiplication of fishing gears was also due to the lax implementation of fishery laws and rules by the local government, as well as the absence of zoning and guidelines for construction of fishing gears.

Table 3-4. Number of stationary fishing structures in the Batan Estuary in 1991, 1999, 2006 and in the 2007 Municipal Fisheries Registry.

Type of Structure	Local Name	Count			
		1991[a]	1999[b]	2006[c]	2007[d]
Fish corral	*taba*, *tigbacoe, tulis*	314	1,554	1,871	1,470
Lift net	*bintahan, batak batak*	59	422	261	132
Filter net	*tangab, saluran*	53	87	112	99
Fish cage	cage	n.d.	14	65	n.d.
TOTAL		426+	2,077	2,309	1,701

[a] Ingles et al. (1992); [b] Babaran et al. (2000); [c] present study; [d] Municipal Fisheries Registry of Batan, Altavas and New Washington

On the other hand, current GPS survey showed another 11% increase in structures between 1999 and 2006. There were 2,309 stationary structures scattered in the rivers and lagoons. Fish corrals were the most favoured type of fishing gear as these appeared dominant in all three surveys and actual registry (Table 3-4). Out of the total 2,309 stationary gears surveyed in 2006, fish corrals was the most numerous (1,871 units). This accounts for 81% of all the fixed gears surveyed. In the rivers, these were very closely constructed side by side, forming chains of 6 to 8 units that block the whole width of a creek. This formation does not only affect the natural flow of water and transport of particles like silt, but also hinders navigation. However, fish corrals were more distant in the wider bay areas and lagoons, extending from 20 to 100 m apart. These are also relatively bigger with a 50-m wing span and more compartments or “play grounds” to lead the fish towards one or more catchment bags.

Lift nets were the second most dominant fixed fishing gear used in the estuary, reaching 261 units (11%). This declined by about half, from 422 units in 1999. Filter nets, however, more than doubled since 1999 with 87 units to 112 in 2006. Filter nets were commonly constructed in chains of two or more units situated in narrow channels with fast flowing water. On the other hand, fish cages tripled in number within half a decade since 1999, signifying a possible shift from capture fishing to cage aquaculture. There were 65 (3%) fish cages found in various locations in the estuary but most were situated in the upper river tributaries. These were mostly for fattening groupers and snappers. Oyster and mussel culture were also widely operated in the estuary employing various techniques like hanging of old shells and rubber tire exterior, but most fishers simply use bamboo stakes. Individual units of these were difficult to determine, thus only their relative distribution are presented in the map (Fig. 3-8).

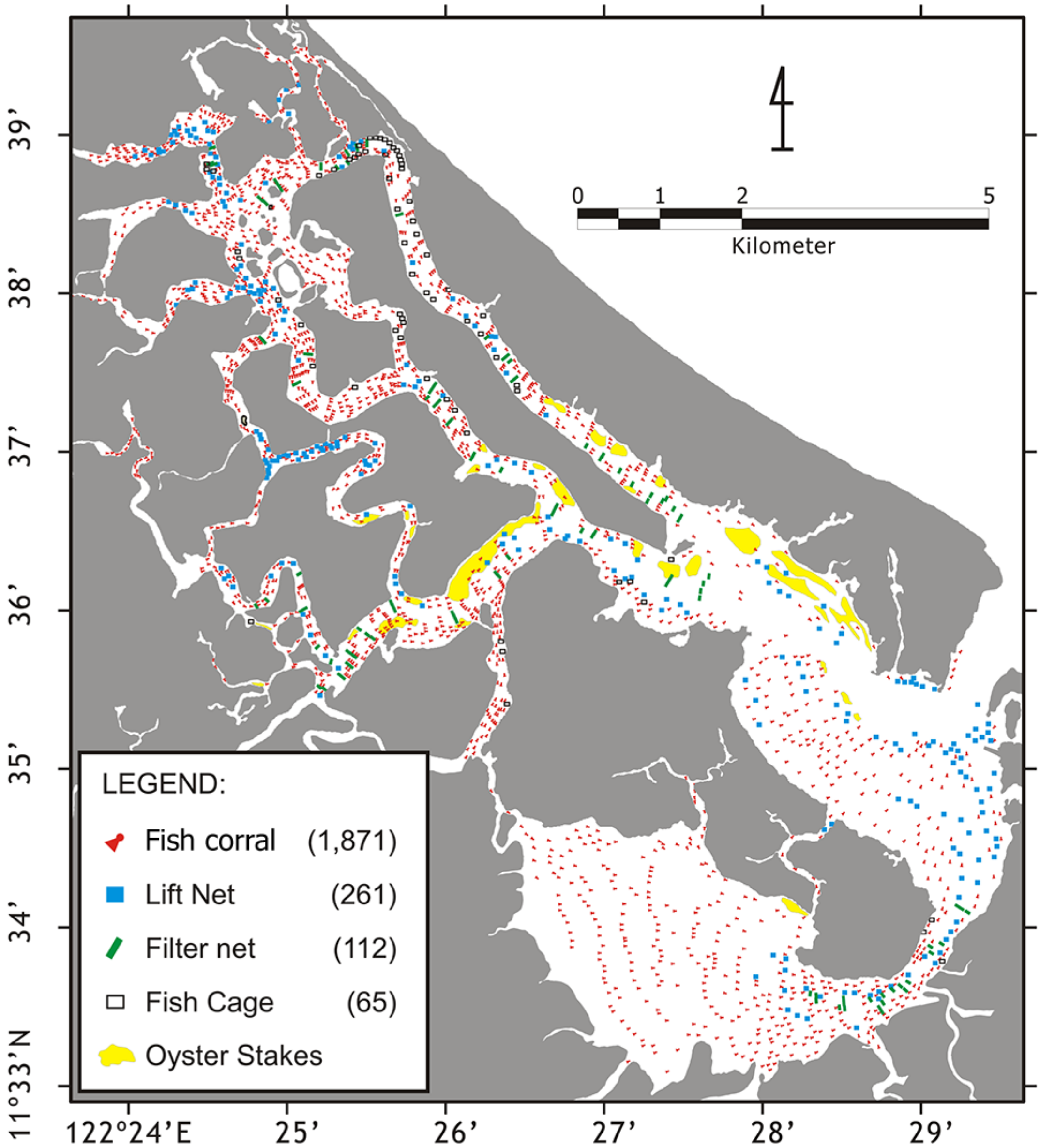

Figure 3-8. Distribution of stationary fishing structures in the Batan Estuary based on actual GPS survey in 2006.

Based on the 2007 combined Municipal Fisheries Registry of the three municipalities in Batan Estuary, only a total of 1,701 (except fish cages) legally registered stationary fishing gears were accounted for (Table 3-4). Our comparable 2006 survey revealed an actual count of 2,244 gears (excluding fish cages). This suggests that 543 or 24% of the total fixed fishing gears were illegally operating in the estuary. These illegal gears were composed of 401 fish corrals, 129 lift nets, and 13 filter nets. This discrepancy clearly shows the weak law enforcement in the Batan Estuary.

3.3.4. Daily Catch

Almost all the stations recorded a mean catch of less than 3 kg per day except for Station B6 with 9.9 kg (Fig. 3-9). In most stations, fish corrals were smaller with a wing span of 10-20 m and a single catchment end. However, fish corrals operated around Station B6 were bigger and more complex. These have leading fences between the wider wings and a series of "playground" compartments to direct fish towards one or two catchment ends. This type of fish corral is locally called *tulis* and targets fish rather than shrimps. Because of their size and higher cost of construction, these big gears are only limited in wider areas in Station B6. For these reasons, Station B6 was excluded in some comparative calculations.

ANOVA with Duncan's Test ($P<0.05$) revealed some significant grouping of stations (Fig. 3-9). Station B6 was clearly a separate group having a much higher catch rate of about 10 kg d^{-1} and 89% of which were fish, thus bearing the only grouping "d". Stations B3 and B5 showed similar properties with R1, R2 and R3 but the geographic separation linked them closer to the other bay/lagoon stations with a common "c" grouping. The *Pinamuc-an* River group (R1, R2 and R3) has a combined mean catch of 1.7 kg d^{-1}, while *Lagatik* River group (R4, R5 and R6) has 0.9 kg d^{-1}.

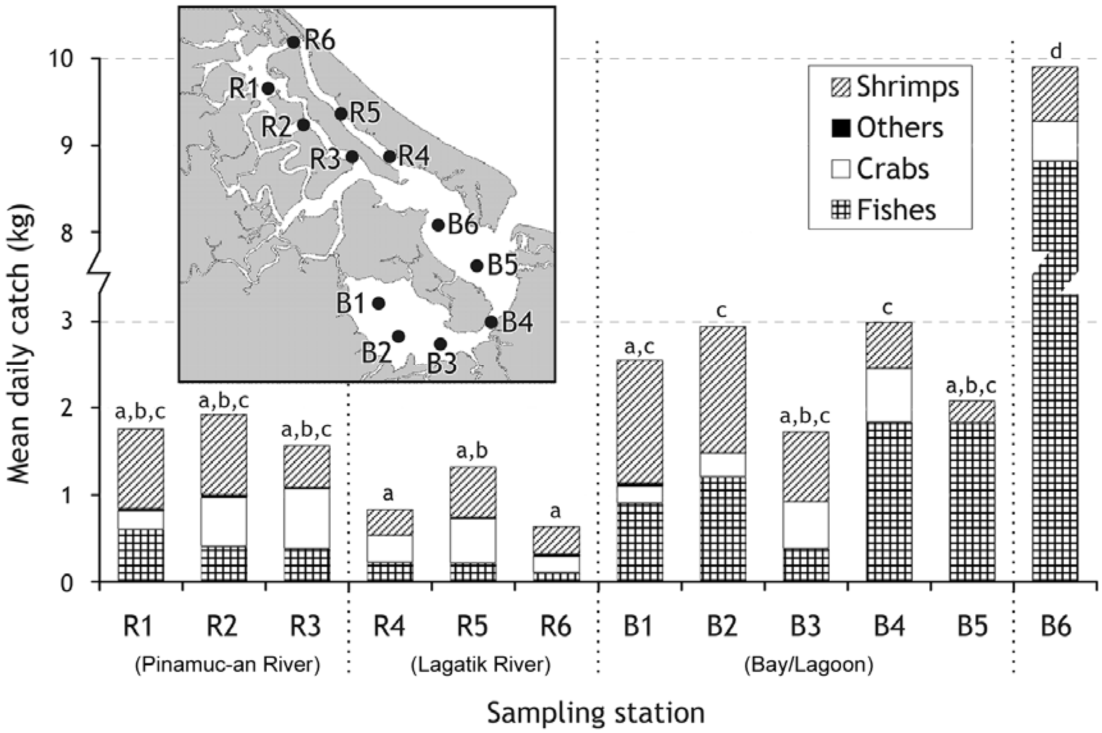

Figure 3-9. Mean daily catch composition of fish corrals at 12 stations (inset) in the Batan Estuary from June to November 2006. Different superscripts denote a significant difference (ANOVA with Duncan MRT, P<0.05) where some grouping can be observed (vertical dotted lines).

The bay/lagoon stations (B1 to B5) produced a higher average catch of 2.5 kg d^{-1}, because fish corrals in these areas are also situated farther apart compared to those in the rivers. Except for stations B6 and B5 that showed occasional catch of bigger-sized fish (being nearer the estuary opening), the other stations only catch smaller fish and crabs with individual mean weight of 6 g and 30 g, respectively. These small sizes cost very little in the market and sometimes only reserved for household consumption.

Despite the relatively lower catch in the river stations, these caught more crustaceans than fish. In the Batan estuary, shrimps offer higher value than fish and crabs. In 1991, total shrimp production in the Batan Estuary was 174.4 tons which is 26.7% of the total production (Ingles et al. 1992). The present data showed that daily catch of fish corrals produced an average of 40% shrimps by weight. In terms of species, the greasyback shrimps *Metapenaeus ensis* dominated 81% of the catch at present, increased from 65% in 1990 (Fig. 5). In terms of value however, fishers prefer the tiger shrimp *Penaeus monodon* because of its high market price. Ingles et al. (1992) noted that *P. monodon* was 61.9% of the total shrimp catch in 1976-1980 but declined to only 6.2% in 1990-1991 (Fig. 3-10). In the recent decade, tiger shrimps are considered to be rare in the wild because fishers can only catch about 3 pieces per day during peak fishing. Some people mentioned that higher catch of tiger shrimps were only associated with escapes from nearby damaged shrimp ponds during floods.

This decline in wild populations of tiger shrimps can be attributed to the destruction of mangroves to give way for culture ponds, the indiscriminate capture of adult spawners for hatchery use, and the non-stop collection of wild fry and juveniles as stocks for aquaculture. Like in other coastal towns in the Philippines, the culture of *P. monodon* in the Batan Estuary started in the mid-1970s (Yap 1999).

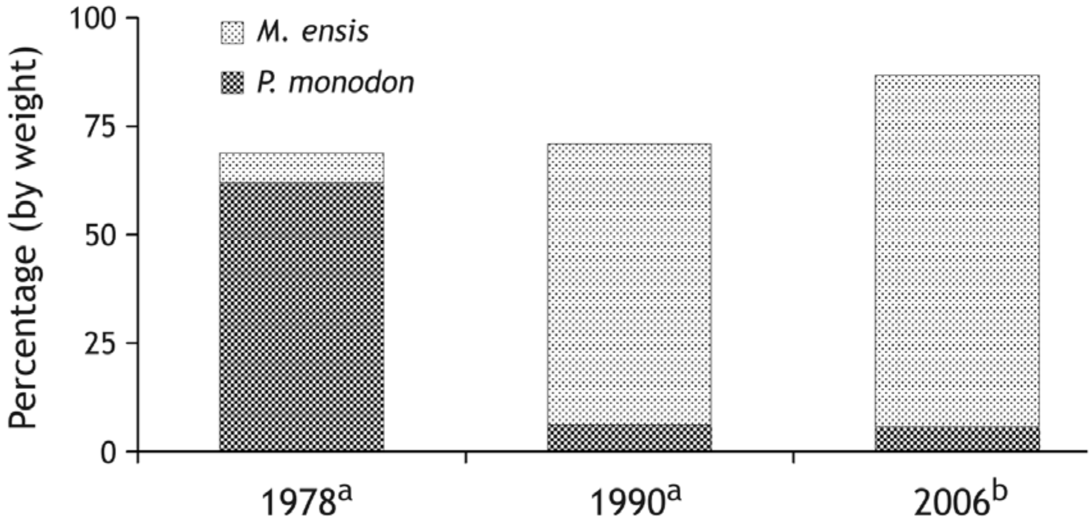

Figure 3-10. Changes in catch composition of fish corrals for *Metapenaeus ensis* and *Penaeus monodon* in the Batan Estuary in 1978, 1990 and 2006.

[a] Ingles et.al. (1992), [b] this study

Different studies have shown the direct relationship between mangrove cover and shrimp populations (Primavera and Lebata 1995; Chong et al. 1996; Primavera 1998; Rajendran and Katherisan 2004). In the case of the Batan Estuary, more than 95% of the original mangroves in 1953 were cleared (Babaran et al. 2000; Altamirano 2007; Altamirano and Kurokura 2009). Thus, it is logical to expect the decline in shrimp production as exemplified by the already rare wild populations of tiger shrimp *P. monodon*.

The Batan Estuary is a shallow water system protected from the open sea. In its pristine condition in the past, juvenile aquatic species especially shrimps are expected to take refuge here. *Penaeus* and *Metapenaeus* juveniles are predominantly distributed in shallow-water estuarine coasts and bays rather than deep-water marine areas (Garcia and Le Reste; Sasekumar et al. 1992; Primavera 1998). At present, results confirmed that smaller juvenile shrimps (< 7 g) were more abundantly caught by fish corrals, and even smaller shrimps (< 3 g) were majorly harvested at the river stations (Fig. 3-11). The very low catch of bigger-sized shrimps suggests that recruitment overfishing in the area is occurring. The overcrowded fishing gears and the continuous harvesting may have overrun the capacity of wild shrimp stocks to recover. This poses a big threat to the future of shrimp fisheries in the Batan Estuary and urgent fisheries management interventions are necessary.

The bay stations were noted earlier to have higher production than the river stations because they capture occasional bigger-sized fish and shrimps. In terms of catch-per-unit-effort (CPUE), the bay areas also showed higher values for both total (2.46 kg $gear^{-1}$ d^{-1}) and shrimp (0.98 kg $gear^{-1}$ d^{-1}) catch. These were almost twice as that of the river areas with a total catch of 1.34 kg $gear^{-1}$ d^{-1} and 0.59 kg $gear^{-1}$ d^{-1} for shrimps. Generally, however, all these CPUE values are still very low.

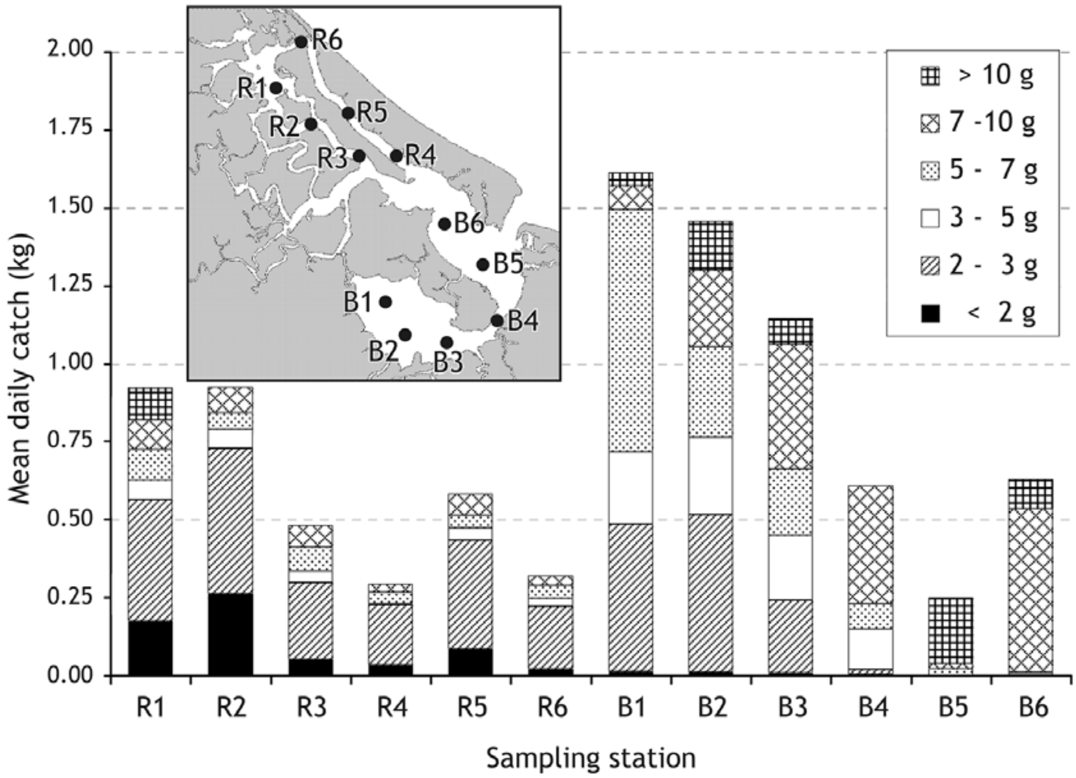

Figure 3-11. Shrimp catch composition by sizes for fish corral in 12 stations within the Batan Estuary in 2006. Legend denotes six size classes.

Together with results from the interview surveys and literature data, the current CPUE figure confirmed the declining trend of inshore fisheries in the Batan Estuary (Table 3-5). The trend shows about 50% decrease in CPUE every decade since 1970. From an abundant catch of about 24 kg d^{-1} in the 70s, fishers only harvest 8-10 kg daily in the 80s and 90s. This was further reduced to only 3 to 5 kg in year 2000. In as short as six years after that, current data shows only an average total of 1.65 ± 0.14 kg d^{-1} and only 0.70 ± 0.01 kg d^{-1} for shrimps.

Table 3-5. Catch-per-unit-effort (CPUE) using corral nets in the Batan Estuary from 1970 to 2006.

Year	CPUE (kg $gear^{-1}$ d^{-1})	Reference
1970	24	This study (interview)
1980	10	This study (interview)
1990	7.66	Ingles et al. 1992
2000	5	This study (interview)
2000	3.44	Babaran et al. 2000
2006	1.65	This study (catch data)

3.4. Chapter Summary and Conclusion

In the 1970s, local fishing communities in the Batan Estuary have more than enough harvest from fishing to support their families. Because harvesting rate was below the rate of resource regeneration and a healthy environment was maintained, a state of a sustainable system was achieved. However, based on experiences of local communities assessed through interview surveys in this study, the declining trend in fishing production in the Batan Estuary was eminent. Responses showed a decrease in daily catch of fish and shrimps from an average of 24 kg in the 1970s to only 5 kg in 2000. This pattern was also true in other coastal fishing grounds in the Philippines like in Manila Bay and San Miguel Bay in Northeast Luzon (Evasco 2000; Mines et al. 1986), and specifically in the Cogtong Bay in central Visayas where average catch also dwindled from about 20 kg in the 1960s, to 10 kg in the 1970s, to only about 5-7 kg in the 1980s (Katon et al. 1998).

In an attempt to increase their catch, the growing population of fishers in the Batan Estuary multiplied their fishing effort by increasing the number of fishing gears. This has lead to an unimaginable increase of 400% in fixed fishing gear count from 1990 to 2000 (Babaran et al. 2000). At present, more than 2,300 stationary fishing structures alone congest the lagoons and rivers, while negatively affecting the natural hydrology as well as limiting navigation and transportation. To make things worse, more than 600 units of these gears were illegally constructed and operated as these do not appear in the official registry of the municipalities (Table 3-4). Nevertheless, this increase in gears did not accompany a corresponding increase in catch. In 1991, a single fixed fishing gear like the fish corral was recorded to have a CPUE of 7.66 kg d^{-1} (Ingles et al. 1992) but decreased to a CPUE of 3.44 kg d^{-1} in 2000 (Babaran et al. 2000). Furthermore, current results showed a much lower CPUE of 1.65 kg $gear^{-1}$ d^{-1}.

The unprecedented overcrowding of fishing structures in the estuary maybe attributed to mismanagement by the government. Being shared by at least three municipalities, the Batan Estuary is also governed by at least three different sets of laws and rules that are sometimes contradictory. At some point, fishing permits were required in the municipality of New Washington but none were required in some parts of the other municipalities. This lack of unified guidelines for fisheries in the whole estuary has lead to various problems. The more general Philippine Fisheries Code (Philippines Republic Act No. 8550, 1998) outlines basic fishery laws but the more detailed municipal ordinances were laid out by the respective local governments. Various laws existed in paper but the actual enforcement was commonly inefficient. For example, it is currently stated in the local ordinance and permits of New Washington that only two units of fish corral may be allowed per fishing household, but surveys showed that some families even operate more than 10 gears. Because of the weak control by the authorities over the activities in the estuary, the local people were rather free to do as they please even without proper guidance. This was triggered by the desperate need to support their poor household to survive.

In the standpoint of total productivity, the Batan Estuary seemed to show improvement. The total annual catch in the estuary improved by 166% between 1990 (654 tons) and 2000 (1,742 tons) (Ingles et al. 1992; Babaran et al. 2000). This figure alone may only provide a false conclusion about the increase in productivity of the estuary. Despite the general increase in total catch by weight, the claim of the local people of declining resources can still be explained. Closer investigation revealed some shift in the general composition of captured species as well as in the sizes of harvested resources. In the past decades, fishers capture larger fish of more profitable species like siganids, groupers and snappers. But recently, catch was dominated by smaller and less commercially important cardinal fish *Apogon*, slipmouths *Leiognathus*, and anchovies *Stolephorus* (Babaran et al. 2000). Shrimps also showed the same negative shift where the high-priced tiger shrimps *Penaeus monodon* that were very adundant in the wild, composing 62% of the total shrimp catch, in the late 1970s decreased to only 6.2% in 1991 (Ingles et al. 1992). Recent survey even showed that *P. monodon* only composed 3% of the total shrimp catch while the fairly-priced *Metapenaeus ensis* dominated 81%. Interview survey showed that a single fishing gear caught an average of 15 kg d^{-1} of shrimps in the 1970s but at present, only a mean of 0.7 kg d^{-1} of shrimps can be harvested by one fish corral. Sizes of captured shrimps also shifted from bigger adults in the past to smaller juveniles as the recent survey results showed (Fig. 3-11). Wild *P. monodon* averaged 74.4 g in 1978 while only half of this weight was caught in 1991 (Ingles et al. 1992). In 2006, very small individual shrimps weighing less than 10 g composed 92% of the total shrimp catch by weight. In terms of quantity, 83% was composed of individuals weighing less than 5 g.

Although many projects have been implemented and various ordinances and laws exist, the usual fisheries problems in the Batan Estuary are still evident. Weak law enforcement and the lack of political will and unity among leaders and the local community further complicate the situation. The interview surveys and actual site monitoring clearly showed that the inshore fishery in the Batan Estuary is failing. Therefore, there is an urgent need for effective measures of rehabilitation.

CHAPTER 4

SHRIMP STOCK ENHANCEMENT IN THE BATAN ESTUARY

CHAPTER 4

SHRIMP STOCK ENHANCEMENT IN THE BATAN ESTUARY

4.1. Introduction

4.1.1. Rationale and objective

Stock enhancement programs, particularly for fish species, have been done extensively since the late 1800s. On the other hand, shrimp stock enhancement initiatives still remain limited; although the earliest shrimp releases were done since the 1960s. The primary aim of shrimp stock enhancement is to increase available shrimps in the wild for commercial capture fisheries as in the USA, Kuwait, Sri Lanka, and Taiwan (Bell et al. 2005). In Japan, the loss of natural coastal habitats and nurseries caused by industrialization since the 1960s has affected wild seeds, hence the need for artificial re-seeding of shrimp juveniles (Hamasaki 2006). Like in Japan, China has excess seeds originally produced for aquaculture and these were used for release in the wild (Wang et al. 2006). Stock enhancement projects in Australia were also done to verify new methods and technology (Loneragan 2006). However, in developing countries like the Philippines, where poverty is widespread especially in rural coastal communities, alleviating the lives of artisanal fishers through better harvest is a major consideration. This paper focuses on the Batan Estuary, central Philippines where the prospects of shrimp stock enhancement were explored.

The implementation of a stock enhancement program requires various steps that need important considerations that encompass disciplines of biology, ecology, and even social aspects. Primarily, defining the purpose of the program deserves upmost attention (Bell et al. 2006; 2008). Aside from the need for environmental and risk assessments (Bartley 2006), it is also very important to establish species- and site-specific requirements for stock enhancement. Loneragan et al. (2006) added that despite the long history of shrimp stock enhancement, systemic studies to develop optimal release strategies do not appear to have been carried out. It is therefore the main objective of this work to conduct specific studies done in the actual site to assess the prospects and requirements of shrimp stock enhancement in the Batan Estuary.

4.1.2. Sources of shrimp stocks

One way of enhancing stocks is using wild-caught juveniles (Bell et al. 2005). However, this is not commonly followed in stock enhancement projects because the supply of shrimp seeds from the wild may not be readily available, their numbers may be diminishing, and cost per individual is relatively higher as in the case of the current site – the Batan Estuary. In this sense, the seeds requirement for stock enhancement may as well be produced in aquaculture facilities or hatcheries.

Several studies have documented defects or abnormalities both in the morphology and behavior of hatchery-reared individuals like in cod *Gadus morhua* (Blaxter 2000), milkfish *Chanos chanos* (Hilomen-Garcia 1997), and blue crab *Callinectes sapidus* (Davis et al. 2005). Hatchery-produced shrimps also have varying survival rates because of unnatural stocking densities like those found with *Penaeus semisulcatus* (Heales et al. 1996) and *Penaeus esculentus* (Loneragan et al. 2004). Based on these and other reports, hatchery-reared juveniles may be less fit than their wild conspecifics (Lebata 2006). This may be attributed to the fact that production of ecologically-fit individuals is not a priority in hatchery operations; rather, focus is given towards higher productivity (Fushimi 2001; Brown and Day 2002).

On the other hand, these inferiorities of hatchery-reared animals can be overcome by employing different release strategies that may improve field survivorship and stock enhancement success (Lebata 2006). A greater scientific understanding of behaviour and ecology of the species in question and long-term monitoring can provide greater insight into the shortfalls of hatchery programmes (Brown and Day 2002). In this paper, the practical source of shrimp stocks for the Batan Estuary is discussed.

4.1.3. Selection of release site

Water condition is an important factor in choosing release sites. Salinity is one consideration where different life stages of shrimps require separate niches of salinity levels. Because *P. monodon* is a euryhaline species and is known to osmoregulate its haemolymph, adults can tolerate wide range of salinity between 20 and 30 ppt (Cawthorne et al. 1983; Solis 1988). Abrupt changes in salinity, however, also affect mortality, although younger prawns (< 40 days post-metamorphosis) can survive in low salinity (as low as 1-2 ppt) water better than older animals and can tolerate short acclimation periods of 6 h to 3 days (Cawthorne et al. 1983). Temperature also determines survival of shrimps where extreme fluctuations can lead to high mortality, and that constant optimal temperature can lead to faster growth. At 30ºC, Jackson and Wang (1998) showed that *P. monodon* can grow double than that at 20ºC within 180 d. Dissolved oxygen in the water should also be far from the lethal level of 0.9 mg L^{-1} (Allan & Maguire 1991).

Like other penaeid shrimps, *P. monodon* larvae migrate from the sea to the mangrove nursery areas where salinities are lower and food is abundant (Turner 1977; Newell et al. 1995; Mohan et al. 1995; Kathiresan and Bingham 2001; Sasekumar et al. 1992; Chong et al. 1996; Primavera 1998; Rajendran and Katherisan 1999, 2004). In areas with ideal salinity and temperature levels, shrimps still prefer fringe mangroves than adjacent sand flats (Ronnback et al. 2002). This preference of areas with complex structures is also confirmed with grass shrimps *P. esculentus* where they grow twice a fast in areas with high (70g m^{-2}) than low (7 g m^{-2}) seagrass biomass in northen Australia (Loneragan et al. 2001). In an experiment to assess diel behavior, large and medium *P. monodon* prefer to use shelters mostly in the day while smaller shrimps prefer to burrow; and they spend 70-90% time feeding at night (Primavera and Lebata 1995). These suggest that release sites for shrimp juveniles are better within areas with complex structures and ideal substrate for higher chances of survival.

4.1.4. Initial rearing and size at release

Despite the trend in earlier shrimp stock enhancement programs that simply broadcast shrimp seeds or post-larvae out into the open coasts, it has been argued that determining the optimum size and/or age at release is important. Subsequently, the method of rearing shrimps until such size is equally essential. Hatchery-raised shrimp stocks can be reared in either ponds (Su et al. 1999; Briggs and Funge-Smith 1994) or in open-area net enclosures and suspended cages (Davenport 1999; Fushimi 1999; Rodriguez et al. 1993). The benefit of rearing in ponds is the relative ease in operations because water and feeding management are already well established even in small-scale aquaculture in the Philippines (Yap 1999). Tiger shrimps *P. monodon* were successfully reared in 10 m × 5 m ponds with concrete walls prior stock enhancement in Taiwan (Su et al. 1999). However, Briggs and Funge-Smith (1994) found out that older ponds (after 6 to 7 culture cycles) tend to show a decrease in growth rates of cultured shrimps. Conversely, if conditions are favourable and with proper water management, growth of shrimps in captivity can be maintained and may not be negatively affected up to a density of 200 m^{-2} (Sandifer et al. 1993). Drawbacks with the use of pond culture prior release include the lack of sufficient acclimation of stocks for the release site and uncertain mortality as caused by transportation from culture site to the release area. It has been a common method to use plastic fry bags to transport postlarvae and juveniles like those used in Sri Lanka *P. monodon* stock enhancement (Davenport 1999).

Shrimp seeds need to be acclimated to the site prior to release, thus the need to rear in net enclosures situated as close as possible to the future release site (Fushimi 1999). In Sri Lanka, *P. monodon* (from PL22) were placed in 1.2 m × 1.2 m suspended nursery cages within the lagoon and achieved a survival of 70-80% in two runs (Davenport 1999). With suspended (hapa) nets, *P. monodon* postlarvae (PL28) can still have high survival of 97% even at high densities of 288 m^{-2} (Rodriguez et al. 1993).

The duration of rearing or culture of shrimp stocks depend on the desired age of shrimps for release. Initial shrimp release initiatives only used seeds directly from hatcheries and broadcasted in the wild like in China and Japan (Fushimi 1999; Wang 2006). In 1963, 1.6 million mysis stage larvae of kuruma prawn *P. japonicus* were released in Japanese waters and in 1965, the release of small juveniles (10 mm total legth) reached 10 million (Fushimi 1999). This method, however, entails many uncertainties especially on shrimp mortality after release (Bell et al. 2006; Loneragan et al. 2006). Later, Fushimi (1999) recommended that kuruma prawns *P. japonicus* with total length of at least 30mm (c.a. 10mm CL) may provide higher chances of survival because at this size, shrimps are already in their benthic stage.

4.1.5. Monitoring and evaluation

To evaluate the success or failure of shrimp stocking initiatives, an efficient method of marking shrimps is important in sorting recaptured stocks from wild catch. The main challenge for shrimp tagging is the difficulty imposed by molting. A number of marking options for shrimps have been tested and improved since the late 1950s, to include various modes of staining, internal or external tags, and cutting of body parts (Farmer 1981; Neal 1969). Table 4-1 summarizes some of the studies on marking and tagging of crustaceans, especially shrimps. Most of these studies use sub-adults and larger juveniles, requiring longer pre-release culture that increases cost. On the other hand, other mass shrimp restocking programs use post-larvae shrimps that cannot be marked because of their very small size. Therefore, shrimps that are to be released should be big enough to be tagged but should not require long culture periods. In this study, juvenile shrimps of about 10 mm carapace length or about 60 days old were marked.

The main concern in choosing a marking method or tag is its efficiency in terms of retention and minimal effects on the commodity's growth, movement and survival. It has been recommended that visual implant elastomers (VIE) and micro wire tags are the more viable options for crustaceans (Davis et al. 2004; Godin et al. 1996; Linnane and Mercer 1998). However, the main limitation for these tags is the cost required for its use. Except those involving ablation of body parts, majority of shrimp marking and tagging studies use specialized materials that are expensive.

Table 4-1. Some studies on different marking and tagging methods for crustaceans (from Altamirano and Kurokura, 2010a).

Species[1]	Setup(Duration)	Marker or Tag	Size (mm CL)	Survival (%)	Retention (%)	Reference
Neocaridina denticulate (S)	Laboratory	Trypan blue/red	15-30 BL[2]			Niwa et al., 1998
Penaeus monodon (S)	Tank (5-6 mo)	Streamer	15	31-35	100	Benzie et al., 1995
			18	37-70	100	
	Pond (5-6 mo)	Streamer	15	30-44		
			18	44-59		
P. esculentus (S)	Tank (~2 mo)	Streamer	12-19	~80		Hill and Wassenberg, 1985
P. plebejus (S)	Pond (2 mo)	Streamer	17-27	35-48		Montgomery and Gray, 1991
P. monodon (S)	Tank (2 mo)	Streamer	16-18	90		Primavera and Caballero, 1992
			18-21	47		
P. esculenlus (S)	Tank (2-3 mo)	Streamer	12-17	75-90		Wassenberg and Kerr, 1990
			15-20	90-93		
P. merguiensis (S)	Tank (2-3 mo)	Streamer	11-17	85-100		
Munida rugosa (L)	Tank (2 mo)	Streamer	<27 to >32	29	100	Claverie and Smith, 2007
		T-bar tags		52	100	
		V.I. Elastomer		95	100	
Macrobrachium rosenbergii (S)	Tank (2.5 mo)	V.I. Elastomer	0.01 BW[3]	100	79	Brown et al., 2003
		V.I. Alpha	<5.5 BW[3]	~99	60	
Jesus verreauxi (S)	Tank (37 mo)	T-anchor, dart	90-104	43-51	78-82	Montgomery and Brett, 1996
		Uropod trim		47	77	
Homarus gammarus (L)	Trays (3 molts)	Micro wire	5-8	82	97	Linnane and Mercer, 1998
			12-16	97	97	
		V.I. Elastomer	5-8	68	100	
			12-16	97	100	
		Rostrum cut	5-8	80	0	
			12-16	99	0	
		Branding	12-16	57	0	
			16-19	90	0	
		Streamer	16-19	97	100	
P. vannamei (S)	Tanks (3 mo)	V.I. Elastomer	<3.92 BW[3]	99-100	91-93	Godin et al., 1996
			21-47 BW[3]	100	93	
Litopenaeus vannamei (S)	Tank (~2 mo)	V.I. Alpha	2.7 BW[3]	81-92	92-98	Arce et al., 2003
			21.5 BW[3]	68-74	80-83	
	Pond (~4 mo)		2.7 BW[3]	90-93	93-97	
			21.5 BW[3]	80-88	83-85	
Callinectes sapidus (C)	Lab (1.5 mo)	V.I. Elastomer	6-25	~58-60	~81-84	Davis et al., 2004
		Micro wire	6-25	~47-60	~92-93	
Litopenaeus setiferus (S)	Tank (1 mo)	Micro wire	30-90 BL[2]	81-100	95-100	Kneib and Huggler, 2001
Litopenaeus vannamei (S)	Lab (4 mo)	Uropod cut	13-16	~98	0	Leano and Liao, 2006
			28-29	~63	~88	
		Uropod trim	13-16	~99	~91	
			28-29	~53	100	
Penaeus japonicus (S)	Lab (~2.5 mo)	Uropod cut	21-73 BL[2]	92	96	Miyajima et al., 1999
	Sea (12 mo)	Uropod cut	35-75 BL[2]		2.4[4]	

[1](S)=shrimps, (L)=lobster, (C)=crab; [2] BL=Body Length (mm); [3]BW=Body Weight (g); [4] recaptured

In this study, low-cost and readily available options for tagging and marking small juvenile shrimp *P. monodon* were compared. Instead of specialized stains, ordinary natural food color (McCormick® and Company, Inc., Maryland) was used that has also been described in some reports and applied to stain other taxa like nematodes (Thies et al. 2002). Ordinary plastic T-bar tags (Bano'k®, Japan), commonly used in tagging clothing merchandise, were also tested as a possible substitute for streamer tags and specialized T-bar tags (Hallprint Pty Ltd., Australia). Uropod trimming, discussed by various authors (Leano and Liao 2006; Miyajima et al. 1999; Toyota et al. 2003), was also tested because it involves no additional costs for materials.

4.1.6. Predation on shrimps

With an idea on ecological dynamics like natural population density and predation on the target species, a more effective plan for stock enhancement can be drafted. For example, total natural mortalities for brown shrimp *Penaeus aztecus* in Galveston Bay, Texas ranged from 23% to 61% within 2 weeks, while predator-exclusion experiments only revealed 3% mortality (Minello et al. 1989). Predation on shrimps *P. monodon*, *M. merguiensis*, and *M. ensis* was lower with mangrove pnuematopohores than with bare substrates (Primavera 1997). In clear water, predation on *P. indicus* was greater with increased shrimp density (Macia et al. 2003). Stocking densities in culture ponds are typically around 32-35 m^{-2} (Jackson and Wang 1998), however natural densities of *P. esculentus* juveniles, for example, rarely exceed 2 m^{-2} in seagrass beds of northern Australia (Loneragan et al. 1994).

4.2. Methodology

The studies on stock enhancement of tiger shrimp *Penaeus monodon* in the Batan Estuary were conducted in two main sites (Fig. 4-1). Experiments requiring earthen ponds with dikes were conducted in the Brackishwater Aquaculture Station of the College of Fisheries and Marine Science (CFMS) of Aklan State University (ASU), New Washington, province of Aklan, Philippines. This station also has a simple wet laboratory where experiments involving the use of aquaria were done. On the other hand, open area experiments and studies simulating the release sites for stock enhancement were conducted at the *Isla Kapispisan* Aquasilviculture and Eco-Park of the Municipality of New Washington, managed by the ASU-CFMS. This is located in the middle of the river system in the northern part of the Batan Estuary (Fig. 4-1).

4.2.1. Source of stocks and release site in the Batan Estuary

There were no experiments conducted to directly answer this concern for the study. However, based on surveys, on-site observations, and available literature, the possible source of shrimp stocks as well as the most probable area of release within the Batan Estuary are discussed in this chapter.

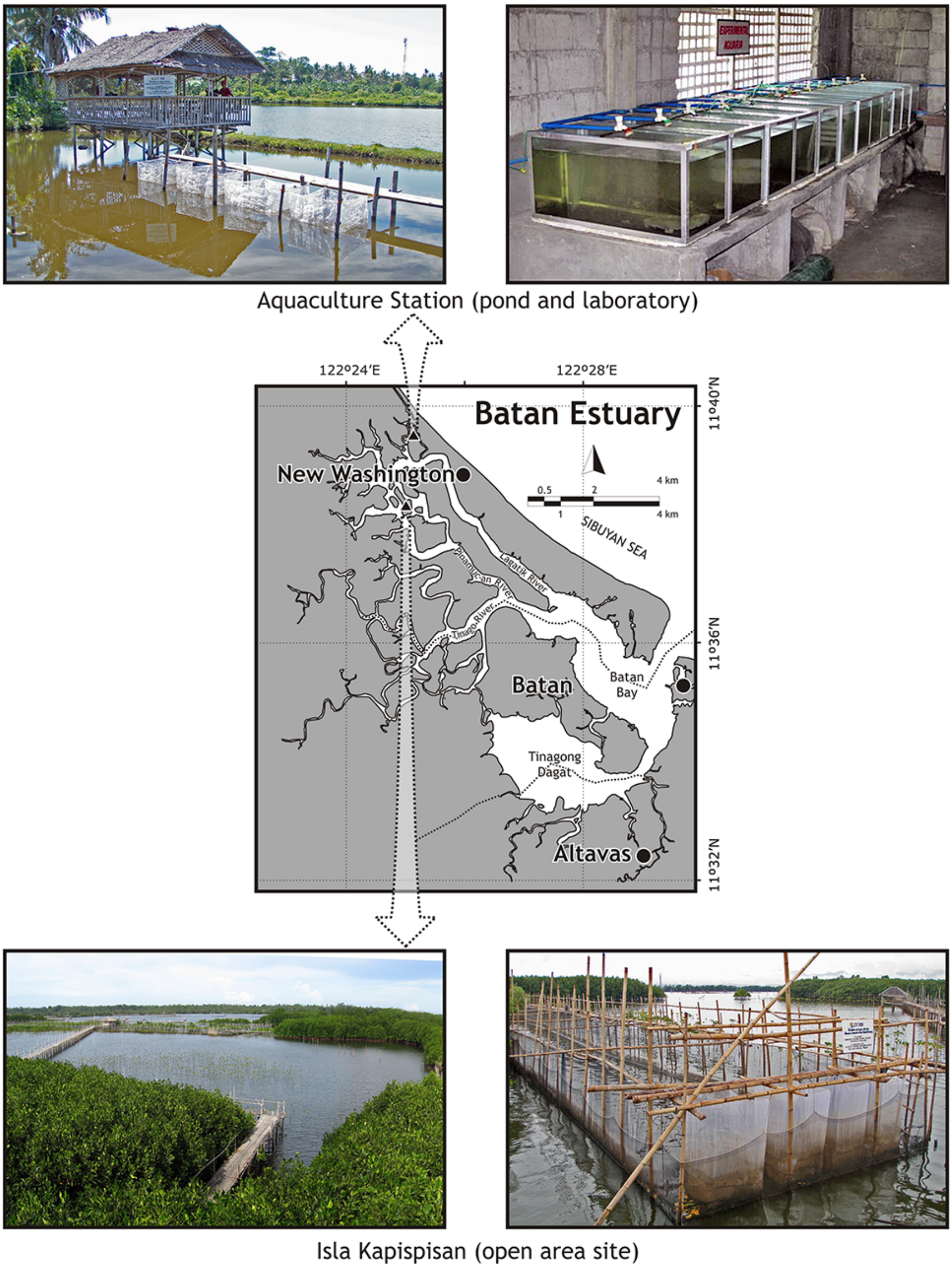

Figure 4-1. Location of experimental sites: (1) Brackishwater Aquaculture Station of the College of Fisheries and Marine Science (CFMS) of Aklan State University; and (2) Isla Kapispisan Aquasilviculture and Eco-Park in New Washington, Aklan.

4.2.2. Determining optimal-age-at-release

In the case of *P. monodon*, there is no study on the optimal-age-at-release for stock enhancement. The main objective of this sub-study was to simulate the release of shrimp juveniles using net enclosures in the planned release site and to compare the growth and survival among three age classes (1 mo-, 2 mo- and 3 mo-old) of shrimp juveniles. This will determine the length of initial shrimp culture prior to release. This study was limited only in determining the acclimation capacity of shrimps, thus other factors such as predation we not accounted for.

Net enclosures measuring 1 m × 2 m with <1 mm mesh size were constructed in the *Isla Kapispisan* site. The bottom portion of the nets was buried in the substrate to allow shrimps to burrow naturally, but hinder them from escaping through. Twelve units of such enclosure nets were used; four replicates for each of the three age class treatments with twenty individual shrimps stocked in each net corresponding to their respective age. This manageable density (10 m^{-2} density) is convenient for monitoring in such small net enclosure used. Although this is higher than the estimated natural density of 2 m^{-2}, survival of *P. monodon* was proven to be not significantly affected by densities up to 40 m^{-2} in an experiment by Allan and Maguire (1992). Initial mean (±s.e.) carapace lengths were: 12±0.19mm for 1-mo class, 21±0.69 for 2-mo class, and 28±0.75 for 3-mo class. Survival and growth of shrimps in terms of carapace length (CL) and body weight (BW) were monitored every week for 8 weeks (February to April, 2008). Water quality like DO, temp, salinity, turbidity and pH was monitored using a Horiba UX-21 probe. Temperature and salinity were also recorded every 10 minutes using an auto-data logger (ACT-HR, Alec Electronics, Japan). Data were tested with ANOVA and Duncan MRT ($P<0.05$) for significance and percentage data were converted to arcsine values prior analysis (Zar, 1999).

4.2.3. Pre-release culture: open vs. pond rearing

Stock enhancement of shrimps requires initial rearing of postlarvae from hatcheries before releasing in the wild. There were two general rearing techniques that were considered: pond rearing and open-area net rearing conducted at the same time at both sites described above (Fig. 4-1). In this study, effects on growth and survival of *P. monodon* postlarvae from PL_{15} until three months old were investigated and compared between these two rearing systems. Shrimp postlarvae PL_{15} were purchased from a nearby hatchery and were initially acclimated in the respective sites. Three replicate 1m × 2 m compartment nets (fine mesh) were prepared inside the pond rearing site and in the open field site, and stocked with 40 pcs of shrimp PL per net compartment. This stocking density (20 m^{-2}) was lower than typical densities used in shrimp culture (32-35 m^{-2}) to moderate effects of density on survival and growth. Supplemental feed was provided *ad libitum* in both sites. Monitoring of physical water quality like DO, temp, salinity, turbidity and pH was done using a Horiba UX-21 multi-probe. Shrimp size (CL and BW) was monitored every week while survival of shrimps was checked every month by counting the remaining shrimp in each net. The whole experiment lasted for 12 weeks or 3 months from November 2007 to January 2008. A second experimental run was also conducted in April to June 2009. *Shapiro-Wilk* test was initially done to check for normality and *Lavene's test* for homoscedasticity; standard *T test* was used for normally distributed data, otherwise, the non-parametric *Mann-Whitney U test* was used. Significance level was established up to $P<0.001$ when available, else $P<0.01$ and $P<0.05$ were also presented.

4.2.4. Comparison among economical shrimp markers

4.2.4.1. Experimental set-up

Hatchery-bred tiger shrimp *P. monodon* porstlarvae (PL15) were acquired (approx. 1000 pcs) from a local hatchery and reared until 2 mo old in suspended hapa nets inside an open pond. A total of 12 aquaria (140 L) were prepared with washed fine sand as substrate (2 cm deep) then filled with filtered water (120 L) from the same rearing pond and creek. Water from each aquarium was drained by 10% daily using a siphon tube. Water was refilled through individual distribution pipes connected to a central holding tank where the filtered source water was collected daily, aided by a submersible electric pump. Constant aeration was supplied using airstones powered by an electric blower. There were three replicate aquaria for each marking treatment, namely: staining, uropod trimming, and T-bar tagging. Another three aquaria were designated as unmarked control replicates. These 12 aquaria were placed adjacent to a wide window in the laboratory to allow natural diel cycles, arranged in one row and alternating among treatments. Prior the actual experiment, tagging trials were done as practice runs for each tagging method to achieve minimal time in marking and to reduce stress of shrimps while out of the water. Fifteen shrimp juveniles were tagged/marked accordingly (as described below) and placed in each aquarium. The same number was also stocked untagged in each control aquaria. Monitoring for growth (CL and BW) was done weekly, as well as for shrimp's survival. Examination of marker retention and/or visibility was also done every week. The experiment lasted for 8 weeks, from 20 April to 15 June, 2008. Finely chopped fish meat was provided as feed daily (1800 H) *ad libitum*. Uneaten food and unwanted particulates in the aquaria were siphoned-out daily during every water change. Water parameters (salinity, temperature, DO, pH) were monitored daily (0900-1000 H) using a Horiba UX-21 multi-parameter probe. A data logger (ACT-HR, Alec Electronics, Japan) was also used to monitor a detailed (10 min interval) trend in salinity and temperature.

4.2.4.2. Marking methods

Three economical marking methods were used in this experiment (Fig. 4-2). First, the common natural food color (McCormick®) was tested as a staining agent with the use of a small (6.35 mm) sterile tuberculin syringe and a 30-gauge needle. A small amount (about 0.01 ml) of red food color was injected ventrally through the articular membrane between the 1st and 2nd abdominal segments. Second, uropod trimming was done using a pair of small fine-tip surgical scissors. Half of the left outer uropod was cut, adapting the methods described by Leano and Liao (2006) and Miyajima et al. (1999). Third, ordinary T-bar tags, commonly used in clothing's price label, were used for tagging shrimps in this experiment. The plastic T-bar tags were about 0.3 mm thick and 11 mm long, giving more than enough room for shrimp's growth until marketable size. Specifically, the Bano'k® 303XL T-bar injector gun was chosen because of its thin and long injector needle. This injector gun drives the T-bar tags from a set of cartridges. The present study adapted the methods for streamer tags on *P. monodon* by Primavera and Caballero (1992) and Wassenberg and Kerr (1990), where the tag was inserted laterally through the middle of the 2nd abdominal segment, exiting and locking through the right side of the body. This location has the fastest wound healing effect (Wassenberg and Kerr 1990).

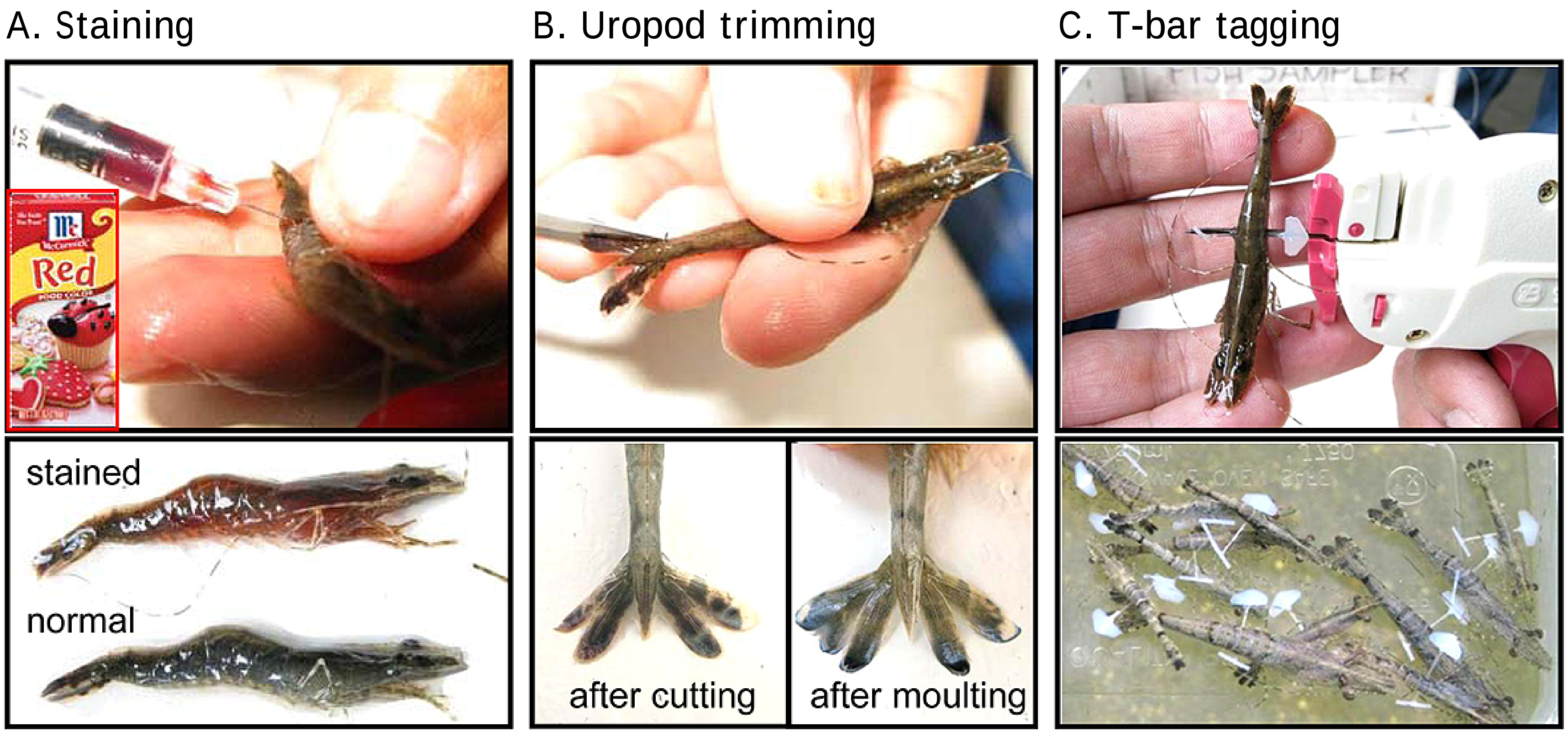

Figure 4-2. Three low-cost marking methods used in tagging shrimp juveniles

4.2.4.3. DATA ANALYSIS

Water quality data (water pH, DO, temperature and salinity) were subjected to two-way ANOVA with marking treatment and measurement week as fixed factors. Initial and weekly growth parameters in terms of CL and BW, and total count of surviving shrimps were recorded to determine growth and survival rates, respectively. Weekly specific growth rates (SGR) were computed for CL and BW using the formula adapted from Ye et al. (2009): SGR (% d^{-1}) = 100 × (ln x_t – ln x_i) / d

where SGR = Specific Growth Rate for CL (%CL d^{-1}) or BW (%BW d^{-1}), x_i = initial measurement, x_t = measurement at a given time t, and d = number of days between measurements. A similar measure for SGR was also used by Primavera and Caballero (1992) to present CL and BW growth rates of *P. monodon* marked with streamers tags.

Survival was represented as a percentage of remaining shrimps from the initial 15 individuals during each weekly monitoring. Marker retention and visibility was examined and recorded as a percentage from among the surviving shrimps per monitoring week. Data were initially tested for normality using Shapiro-Wilk test, and for homoscedasticity using Levene's test**.** Percentage data were transformed to arcsine prior analyses to improve homogeneity of variances (Zar 1999). Then, data analysis proceeded with ANOVA and further tested with Tukey's HSD multiple comparison tests were performed. Comparisons were made to determine differences among treatments and control on the survival and growth of shrimps, as well as on tag retention. Significance was established at $P<0.05$. Statistical analyses were performed with SPSS® statistical software version 14 (SPSS Inc., Chicago, IL).

4.2.5. Predation on shrimps

4.2.5.1. Natural shrimp predator survey

The initial survey of fishes inside the *Isla Kapispisan* area was done by dragging a seine net (2 × 10 m, 2 m^2 bag end opening) for 50 m on sandy-muddy areas, with each drag ending at a river bank lined with mangroves. A total of 6 replicate drags were done within the area for both day and night sampling. Sample collected were stored in 10% formalin for sorting and identification in the laboratory using Carpenter and Niem (2001). Another survey approach was done using shrimp tethering, where actual live juvenile shrimps were tethered by the telson with a small hook and 50 cm fine monofilament line. Twenty shrimps were used, arranged in a long-line style of deployment at 1.5 m interval. Hooked predators were collected, stored in 10% formalin and identified in the laboratory.

4.2.5.2. Predation on shrimps: laboratory experiment

A microcosm experiment using aquaria simulating three ecosystems (*Sonneratia* mangrove area with pneumatophore structures, *Rhizophora* mangrove area with prop root structures, and bare substrate area) was conducted to assess predation on *P. monodon* juveniles in these habitats. Prior set-up, natural densities of both *Rhizophora* prop roots and *Sonneratia* pnuematophores were surveyed in the field by counting root structures within 1 × 1 m quadrats from 5 ramdom replicates for each habitat. These natural densities of structures were replicated in the aquaria using actual roots taken from the field. Three replicate aquaria (40 × 90 × 50 cm) with sandy-muddy substrate (2 cm) were used for each habitat treatment (Fig. 4-3). Filtered creek water was used and was allowed to settle to achieve clear visibility.

(A) *Sonneratia* (B) *Rhizophora* (C) bare substrate

Figure 4-3. Experimental set-up for juvenile shrimp predation on three microcosm habitats: (A) *Sonneratia* mangrove area, (B) *Rhizophora* mangrove area, and (C) bare substrate area

Two fish predators were tested: spotted green goby *Acentrogobius viridipunctatus* (13.3-15.1 cm total length) and mangrove snapper *Lutjanus argentimaculatus* (13.5-14.6 cm total length). All fishes were collected at nearby mangrove creeks and starved for about two days to minimize effect of undigested food in their stomach. Experiments with each predator species were done in separate trials. Five juvenile shrimps (6-7 mm carapace length) were used in each aquarium, along with a single predator fish. At the start of the experiment, fish and shrimps were separated at both ends of the aquarium with a net placed in the middle, to allow acclimation and familiarization of the environment. After 24 h, the separator net was removed and noted as hour zero. Survival of shrimps after 6 hours was then monitored by counting remaining shrimps in each aquarium and expressed as a percentage. Data was converted to arcsine prior examination with ANOVA. Significant difference between predator species was also tested separately by treatments with Student's *t*-test.

4.2.5.3. Predation on shrimps: field tethering experiment

A field experiment using tethering method for juvenile shrimps was tested in this study, in parallel with the laboratory experiment of assessing the survival of shrimp juveniles in different habitats. Similarly, in this experiment, three areas were compared: (1) barren substrate, (2) *Rhizophora* mangrove area, and (3) *Sonneratia* mangrove area (Fig. 4-4). Each habitat was located adjacent (15 to 20 m) the other to minimize variability of other factors and hasten the monitoring process. Separate experimental runs were made for daytime and night-time predation assessments.

Tethering was done with the use of 50 cm fine monofilament line (2 kg strength rating) secured on a small barbed hook (scale No. 2, 4 mm total length) and

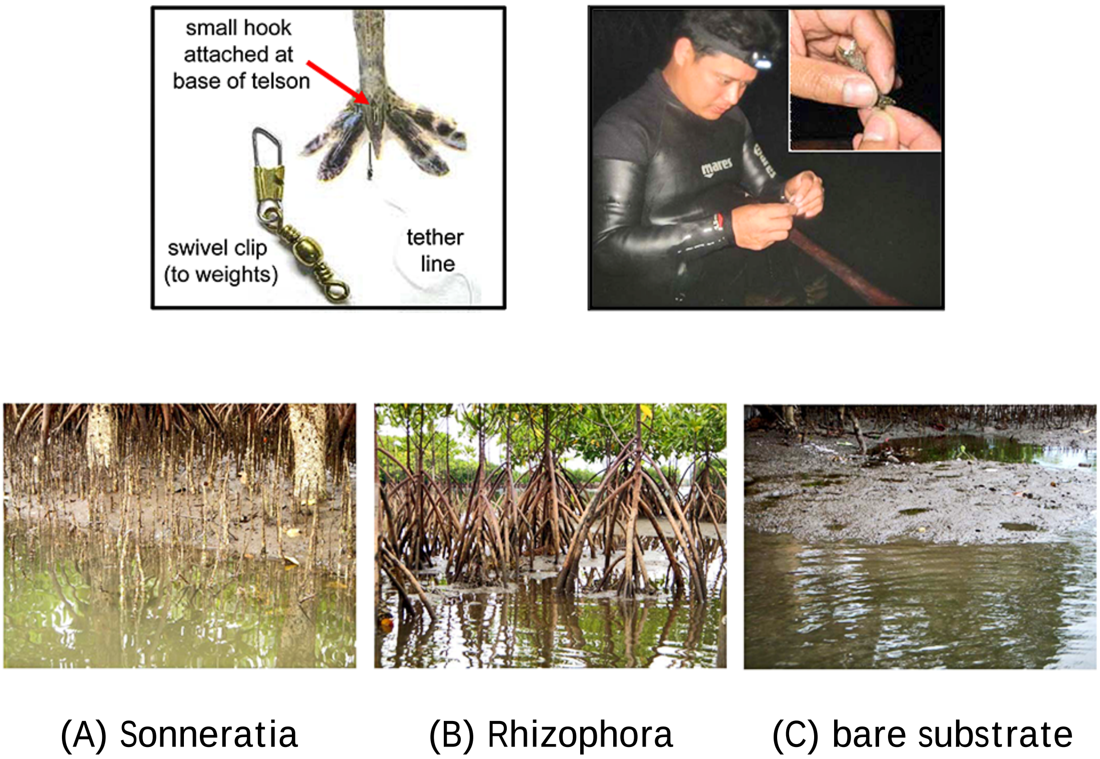

Figure 4-4. Tethering method used in the field predation experiment (above) on three adjacent habitats in the *Isla Kapispisan* site: (A) *Sonneratia* mangrove area, (B) *Rhizophora* mangrove area, and (C) bare substrate area

attached at base of the shrimp's telson. We found that the telson was a better location for attaching the tether hook than the mid-dorsal cephalothorax as used by Kneib and Scheele (2000) on grass shrimps *Palaemonetes pugio*. Initial numerous tests on this method in the laboratory proved 100% retention from natural flicking, swimming and burrowing of shrimps. Additional tests by hanging and manually jigging the tethered shrimps confirmed this reliability. It was also observed that normal walking, swimming and burrowing of shrimps were not affected by the location of the tether hook. The only limitation observed was the length of the tether line. In the actual experiment, the other end of tether line was attached to a free-swivel connector which was hooked to a lead weight, allowing it to be secured at a fixed point when deployed. This weight was then attached to another line with a rubber float at the end which can be easily spotted during monitoring.

A total of 180 small juvenile shrimps (7-11 mm CL) were tethered in this experiment. Five shrimps were used for each treatment habitat during each experimental run, with seven replicate runs conducted for both daytime and night-time trials. Tethered shrimps were randomly deployed within each habitat, but not within 2 meters of each other. Simultaneous deployment among three treatment sites was ideal, but limited to only one team and a single raft, shrimp deployment among habitats in the same experimental replicate run were done so within 15 minutes. A small inflatable raft was used during monitoring to minimized substrate disturbance, as compared to walking or swimming between treatment habitats. Monitoring of shrimp survival was done by lifting the tether line every 15 min for 2 h. Shrimps thatsurvived were immediately lowered back to the same location to be monitored in the next 15 min. Tether lines with missing shrimps were recorded as mortality. Hooked predators were also noted. Survival data were converted to log (x+1) prior statistical analysis with three-way

ANOVA. Day and night trials were also analysed separately with two-way ANOVA and Scheffe's Test to detect specific differences between these two diel phases. Results were also presented as a chart fitted with logarithmic regression lines, with which 100% mortality was estimated for each habitat during of day and night tethering.

4.3. Results and Discussion

4.3.1. Source of P. monodon seeds for the Batan Estuary

In the 70s and 80s, there was an abundance of tiger shrimp *P. monodon* broodstock and spawners in and around the Batan Estuary that were observed all throughout the year which peaked around November (Fig. 4-5). Consequently, tiger shrimp larvae can also be found all year-round especially in the inner rivers of the estuary (Fig. 4-6). For these reason, it was customary for fishers to harvest wild young shrimps and juveniles from shorelines and river banks using triangular skimming nets for use in small-scale aquaculture. Recently, however, the supply of wild *P. monodon* larvae in the area was observed to have dramatically declined. Local aquaculture farmers preferring to use wild shrimp stocks rely on collections from other provinces like Antique (western coast of Panay Island) which can take at least 4 hours for transportation. Despite the claim that ample supply of shrimp seeds from other provinces is available at any time, costs are still relatively expensive at about PhP (Phillippine Peso) 0.40 per individual shrimp. Locally-sourced wild *P. monodon* juveniles from within the Batan Estuary area even cost more, reaching PhP 0.50-0.60 each. In contrast, hatchery-bred shrimp larvae (at PL_{10} to PL_{15}) only presently cost PhP 0.10 each.

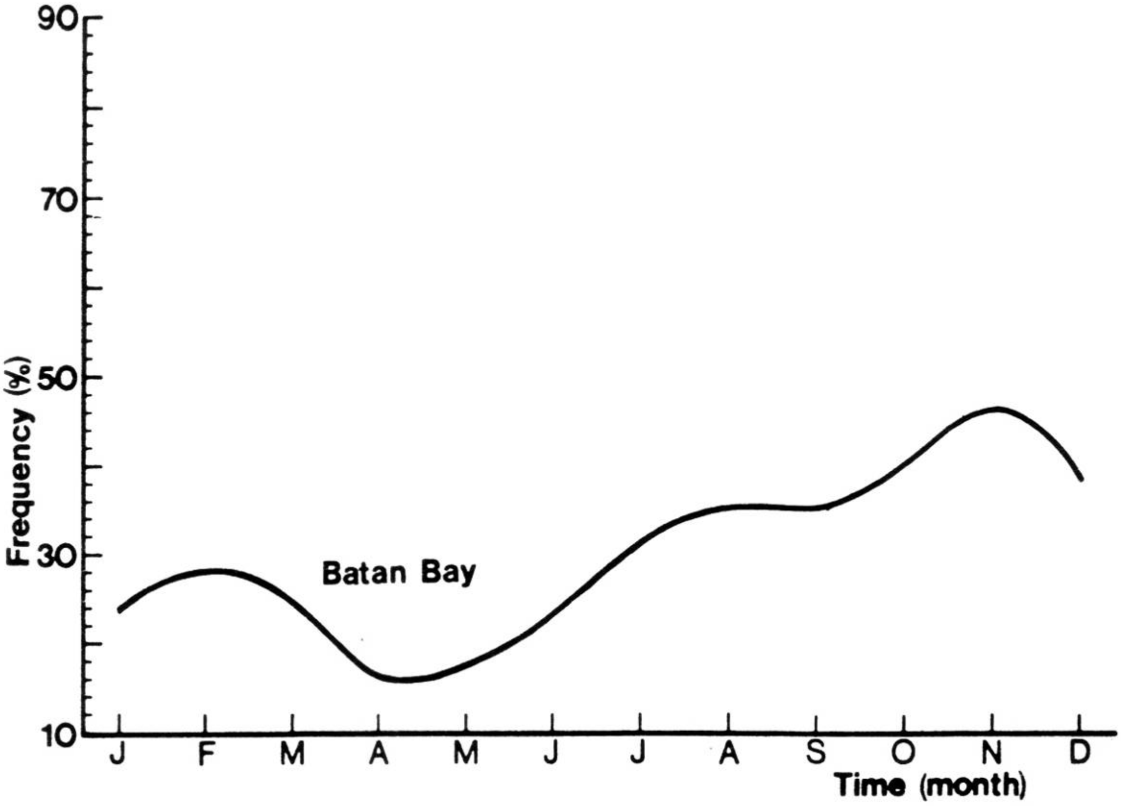

Figure 4-5. Monthly occurrence of *P. monodon* spawners in the Batan Estuary from 1976 to 1979 (from Motoh 1981).

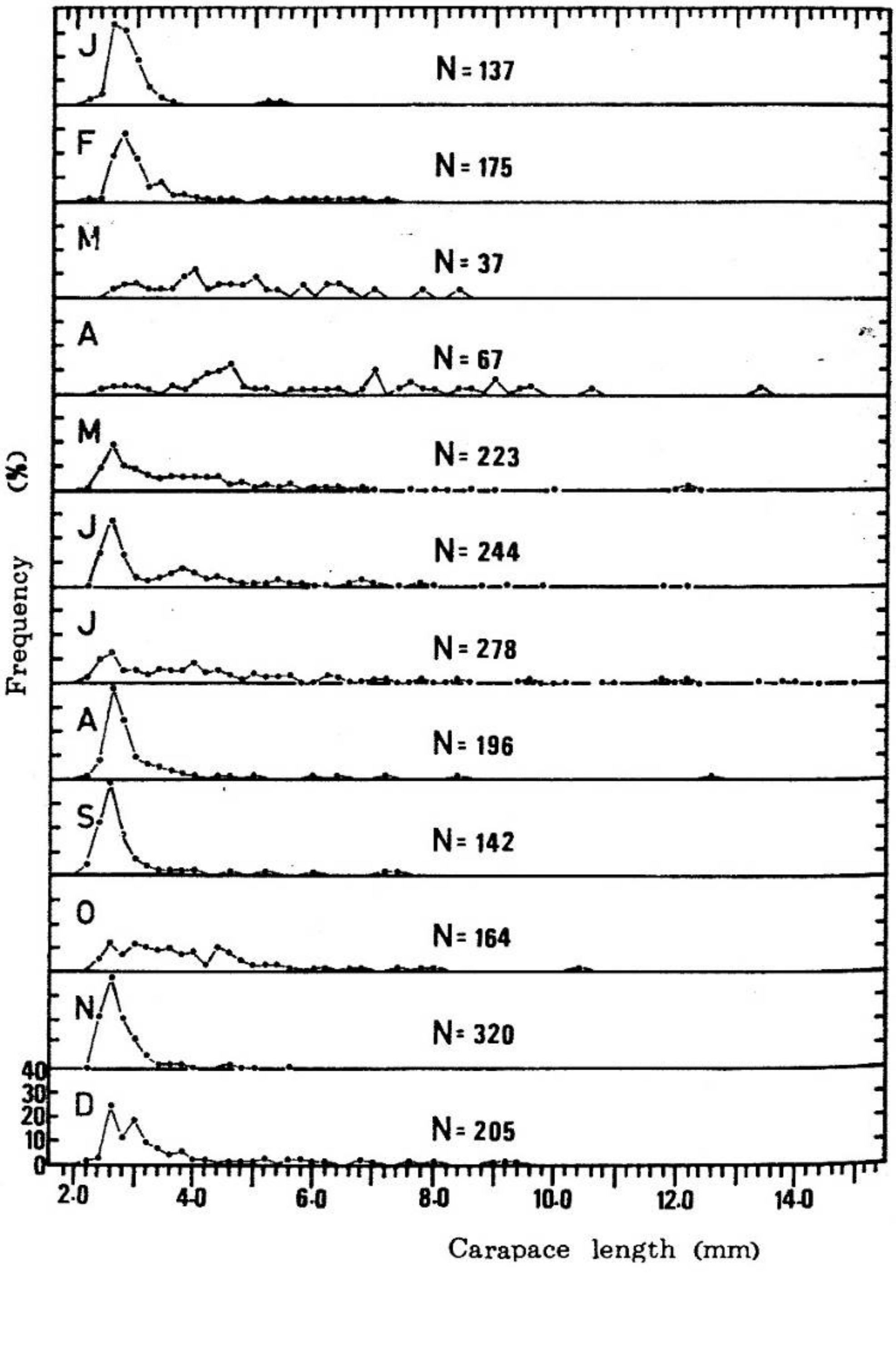

Figure 4-6. Monthly size distribution of the postlaval *P. monodon* collected at the interior portion of Batan Bay (Estuary) from 1977 to 1979 (from Motoh 1981).

During the peak of shrimp aquaculture in the 80s, hatchery facilities have grown in number along the coasts of Aklan and around the Batan Estuary. However, the onset of shrimp diseases that caused the fall of shrimp aquaculture in the 80's and 90's in the country, also led to the closure of most hatchery facilities in the area. However, two shrimp hatcheries still remain in the immediate town of New Washington (minutes away from the estuary) and at least 6 facilities are still in operation in the nearby (30-45 mins away) town of Makato, still in the province of Aklan.

With the available choices of hatcheries in close proximity to the Batan Estuary, and with the lower cost of hatchery-produced seeds compared to wild counterparts, it is most practical to consider sourcing of stocks from these breeding facilities, especially if the stock enhancement program requires great quantities in the order of millions. However, it should still be necessary to impose strict quality control over the operations of the chosen hatchery – from the source of spawners, water quality, and disease control to advanced considerations like genetics.

4.3.2. Specific site for a shrimp stock release program in the Batan Estuary

As mentioned earlier, it is important to primarily consider the ecological aspects of a future release site. Documented here in Chapter 2, the Batan Estuary exemplifies a typical estuary especially in terms of salinity gradients with lower salinities (less than 20 ppt) found in the upper rivers, increasing concentration downstream towards the only opening in the southern portion of the system.

Also, because the upper river areas are shallower, water temperature tended to be warmer there relative to the deeper lagoons in normal conditions (Fig. 2-6). The natural life cycle of *P. monodon* showed that young larvae and juveniles migrate from the sea into low salinity estuaries (Fig. 1-7). It is also ideal to have higher temperature levels (around 30 ºC) for faster growth of shrimps (Jackson and Wang 1998). Since stocks to be released are younger juveniles, these are ecologically much suited in places of lower salinity and relatively warmer waters in the upper river areas of the Batan Estuary.

Aside from water conditions, juvenile penaeid shrimps also prefer to inhabit areas with complex structures like seagrass beds or mangrove roots rather than areas with low vegetation or totally barren like mudflats (Ronnback et al. 2002; Loneragan et al. 2001). Specifically, *P. monodon* juveniles prefer mangrove areas because they have been found to use mangrove root structures as shelter (Primavera and Lebata 1995) and to escape predators (Primavera 1997). It is therefore suggested that release sites for future *P. monodon* stock enhancement should be in areas with considerable cover of mangroves.

Although it is presented here in Chapter 3, that mangroves in the Batan Estuary have been almost totally destroyed, one specific area in the upper rivers has promising potentials. The *Isla Kapispisan* still maintained small patches of natural *Sonneratia* trees and since late 1990s, plantation of *Rhizophora* species have been done. This 32-ha area was established as an integrated mangrove aquasilviculture and ecotourism site, managed by the College of Fisheries and Marine Science (CFMS), Aklan State University (ASU) with collaboration with the local government of the Municipality New Washington. In this area, a 12-ha abandoned pond that is being reverted back to a mangrove forest since 1999. At present, tall *Rhizophora* trees are to be found concentrated where original earthen dikes were and additional seedlings are being planted every year. This area has then been considered as a reserve, thereby limiting access for fishing by local residents within its 32-ha span.

Being located in the upper rivers of the Batan Estuary with ideal water conditions for small fish and shrimps, and the added benefit of being a protected mangrove area, the *Isla Kapispisan* can be recommended as the probable site for future shrimp stock enhancement activity. However, weather conditions must be carefully considered prior to shrimp release activities because heavy rains may cause abrupt changes in salinity and temperature that may have adverse effects on shrimp's survival .

4.3.3. Optimal age of P. monodon juveniles for release in Isla Kapispisan

Because the *Isla Kapispisan* area was found to be the possible site for release of shrimps in a restocking program, field experiments in this study were conducted within its boundary. In this section of the study, the optimal age of shrimps to be released in *Isla Kapispisan* was determined from among three age classes: 1-mo old, 2-mo old, or 3-mo old *P. monodon* juveniles. Water parameters were within normal levels throughout the experiment with the following values (mean±s.e.): water pH (7.68±0.05), turbidity (72.46±4.36 g l^{-1}), dissolved oxygen (6.65±0.24 mg l^{-1}), temperature (28.27±0.35ºC) and salinity (18.93±0.71ppt).

Results showed that changes in CL among the three age classes are comparable and not significantly different (ANOVA, P>0.05) throughout the experiment, although it was observed that smaller shrimps tend to have faster CL increase in the first three weeks of culture (Fig. 4-7). During this period, 1-mo old juveniles grew by 6-10 mm CL wk^{-1} while 2-mo old shrimps grew by 5-7 mm Cl wk^{-1}, and the 3-mo old class only increased in carapace length by 3-6 mm CL wk^{-1}. This faster growth by smaller juveniles was also confirmed in a study by Primavera et al. (1998), where nursery and growout *P. monodon* have a higher growth slope than bigger broodstock. However, 2-mo old shrimps gained faster growth after 1 month at 8 mm CL wk^{-1}, reaching the same average size as that of the 3-mo old class, whose growth was stable from the start at about 4-5 mm CL wk^{-1}. The rate of growth for 1-mo old shrimps showed a slight decline to only about 2 mm CL wk^{-1} after 11 weeks. These results can be attributed to a more efficient acclimation by 2-mo old shrimps to the given conditions (especially salinity) of the site which may be closer to what is required for this specific life stage of the shrimp. Having acclimated well and quickly, 2-mo old shrimps became less stressed, and food assimilation became more efficient, resulting to better growth compared to other age classes.

In terms of survival, 3-mo old shrimps showed significantly lower survival (ANOVA and Duncan Tests, $P<0.05$) from the first week of monitoring (Fig. 4-8). Although it levelled off at 37% survival from week 5 onwards, it was still significantly lower than the other two size classes. Both 1-mo old and 2-mo old classes have higher survival rates (80-87%) and were not significantly different until week 5. However, starting on the 7th week, 2-mo old shrimps showed significantly higher survival (maintained at 87%) than the other two groups. Decline in survival was then observed for 1-mo and 2-mo old classes beginning the 11th week, while 3-mo old shrimps maintained their number at 37% survival until the end of the 15th week. This result may be associated with the low salinity (around 18 ppt) in the experiment site that favours much smaller and younger shrimps. It is known that younger shrimp juveniles prefer lower salinities than larger shrimps (Cawthorne et al. 1983; Solis, 1988), or older (3-mo old) shrimps.

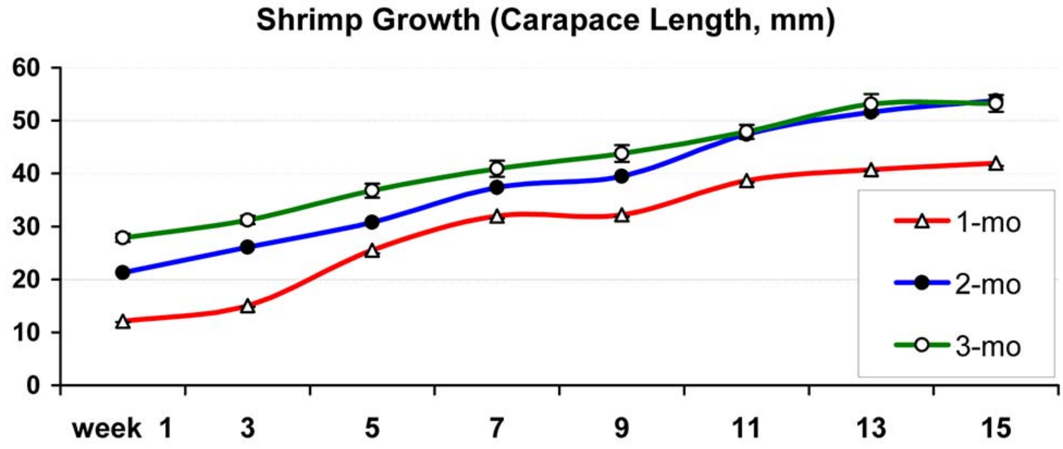

Figure 4-7. Growth of *P. monodon* juveniles at three age-classes (1-mo, 2-mo, 3-mo old) in rearing net enclosures for 15 weeks at the Isla Kapispisan area, New Washington, Aklan.

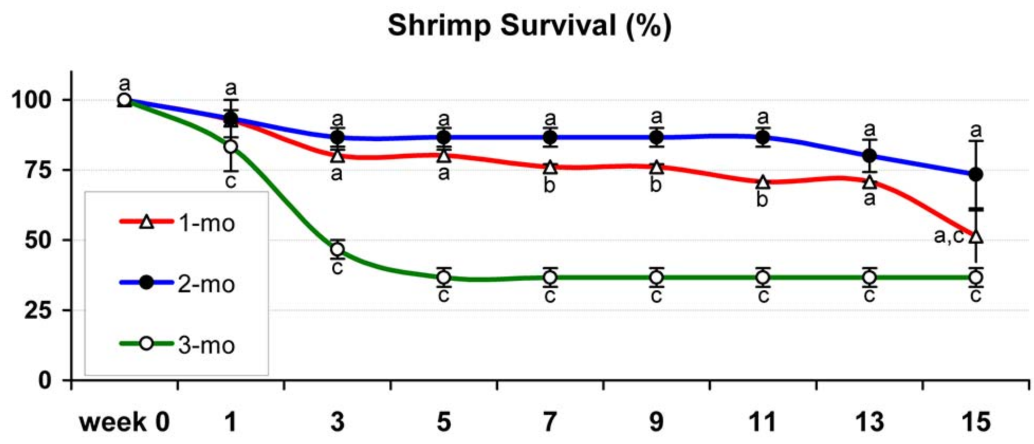

Figure 4-8. Survival of *P. monodon* juveniles at three age-classes (1-mo, 2-mo, 3-mo old) in rearing net enclosures for 15 weeks at the Isla Kapispisan area, New Washington, Aklan. Different superscripts denote significant difference (ANOVA with Duncan's MRT, P<0.05).

4.3.4. Pre-release rearing method

Both pond and open area rearing treatments had similar effect on growth in terms of carapace length where shrimps doubled their size after the first week of monitoring (week 5). Thereafter, however, shrimps reared in the pond showed significantly higher (T-test or Mann-Whitnney U test, $P<0.01$) growth than those reared in the open area (Fig. 4-9). Pond culture of shrimps also has significantly higher growth in terms of body weight compared with open area rearing (Fig. 4-10). Being provided with equal amount of supplemental feed in both sites, the higher growth shown by shrimps in the pond site could mean more efficient food conversion that may also be related to the relatively stable conditions in the pond compared with the open area.

Survival of shrimps also favoured those in the pond especially in their 2nd month (Fig. 4-11). At this time, pond rearing was significantly higher (85.00±7.64 %) than open area rearing (38.33±9.61 %) (T-test, $P=0.019$). Even at their 3rd month, shrimps reared in the pond have higher survival at 42.50±6.61 % (although not significantly different, T-test, $P=0.064$) than those reared in the open area with only 23.33±3.63 %.

In terms of shrimps' growth and survival, rearing in earthen ponds clearly showed higher advantages. This is especially due to relatively more stable conditions in the ponds where water level was maintained at the same depth (0.5 m) all throughout the experiment, while the open area sites are subjected to natural tide cycles fluctuating from 2 m to 0.2 m at the rearing sites. Although, water changes in the ponds were also regularly done, changes in water parameters were not abrupt, except when during heavy rains where salinity may decrease (Fig. 4-8). On the other hand, salinity changes in the open area are dependent on the natural flood and ebb

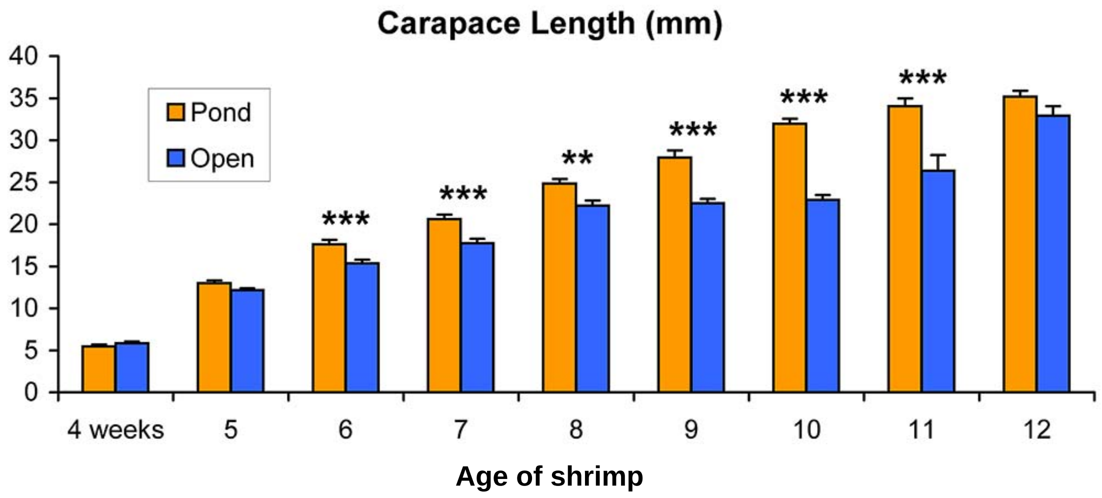

Figure 4-9. Growth (in CL) of *P. monodon* juveniles cultured in earthen pond and open area nets in *Isla Kapispisan* for 12 weeks. Significant difference established at **(P<0.01), ***(P<0.001) using T-test and Mann-Whitney U test.

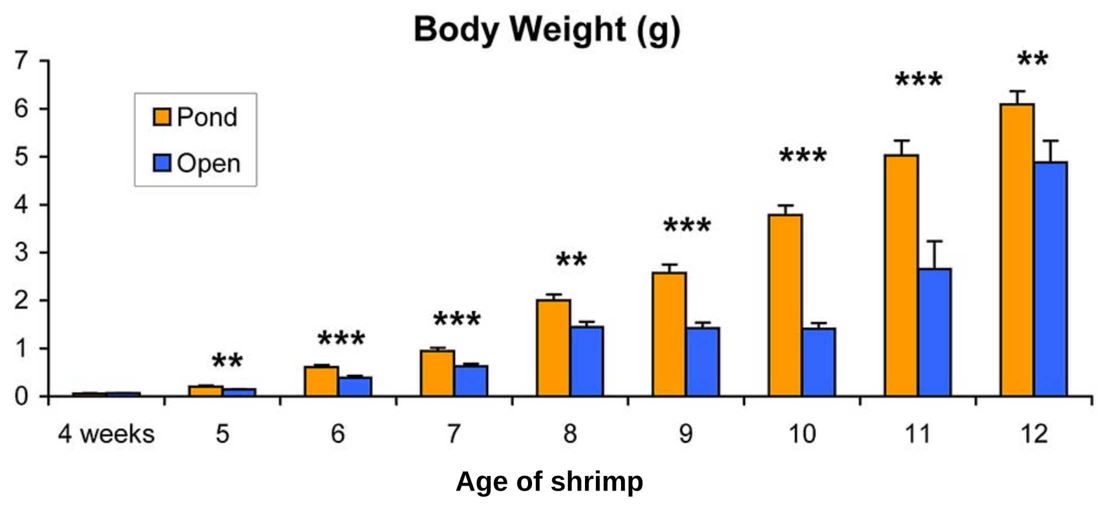

Figure 4-10. Growth (in BW) of *P. monodon* juveniles cultured in earthen pond and open area nets in *Isla Kapispisan* for 12 weeks. Significant difference established at **(P<0.01), ***(P<0.001) using T-test and Mann-Whitney U test.

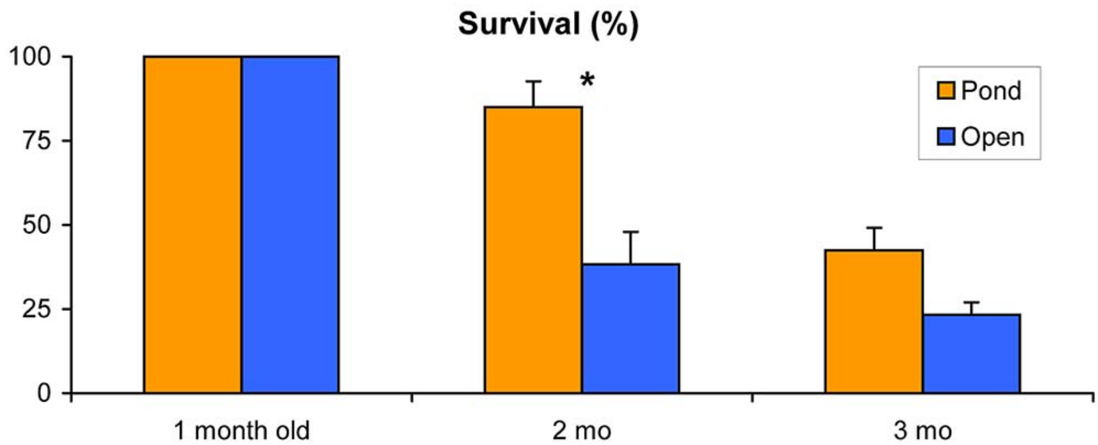

Figure 4-11. Survival of *P. monodon* juveniles cultured in earthen pond and open area nets in *Isla Kapispisan* for 12 weeks. Significant difference established at **(P<0.01), ***(P<0.001) using T-test and Mann-Whitney U test.

tides. Although heavy rains occurred during the 24-h monitoring, and salinity dropped in the ponds site, the open area showed some net increase in salinity as the flood tide enters from the sea (Fig. 4-12). Generally, however, physical water quality were quite stable and within acceptable levels throughout the experiment (Fig. 4-13).

4.3.5. Economical shrimp markers

4.3.5.1. Water condition

Water pH, dissolved oxygen (DO), salinity and temperature were constantly monitored from April to June, 2008 and showed no significant differences among treatments on every monitoring week (two-way ANOVA, treatment*week, P>0.05). Average measurements (mean ± s.d.) of these are as follows: pH, 7.77±0.89; DO, 3.83±0.66 mg L^{-1}; salinity, 18.80±1.77 ppt; and temperature, 26.96±2.59 ºC. Since aeration was sustained and water exchange was maintained, dissolved oxygen was relatively stable throughout the experiment, as well as with pH. Some fluctuations in temperature and salinity were recorded during the sustained rains in May but no drastic changes occurred that may have affected the shrimps.

4.3.5.2. Shrimp's growth

Specific growth rates in terms of % CL d^{-1} showed no significant differences among treatments and control within the 8-week period (ANOVA, P>0.05). The trend in CL changes between monitoring weeks suggests two molting stages within 8 weeks (Fig. 4-14). Results confirmed rapid molting and growth within the first 2 weeks after marking, reaching an overall average CL change of 0.75 ± 0.03 %CL d^{-1} after week 1 and 1.29 ± 0.14 %CL d^{-1} on week 2. Observations also indicated that about 75% of the experimental shrimps molted within these first two weeks. On week 3, zero

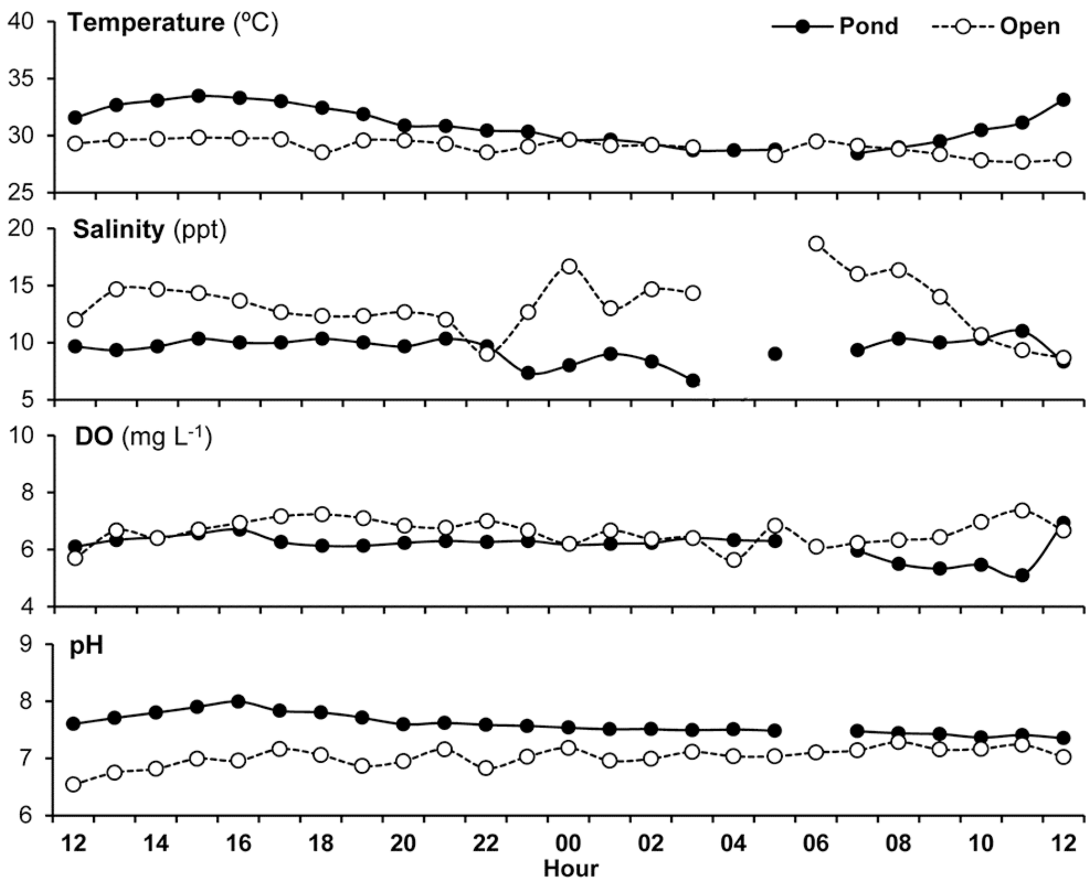

Figure 4-12. Monitoring of water parameters for 24 h in both pond and open area rearing sites in November 2007.

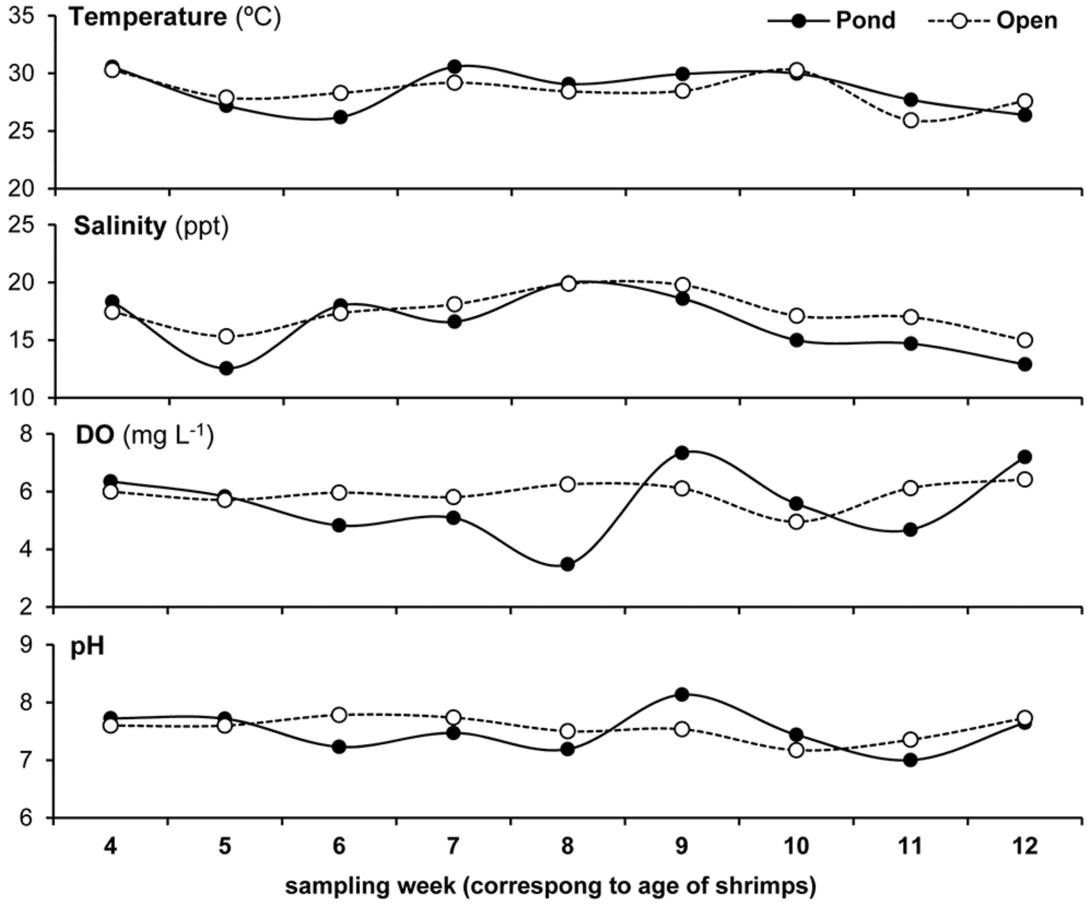

Figure 4-13. Weekly physical water parameters for the pond and open area rearing sites within the duration of experiment (November 2007 to January 2008).

CL growth was recorded which was significantly lower (ANOVA, Tukey's HSD, $P<0.05$) than the previous week indicative of intermolt period where the carapace was becoming rigid (Fig. 4-14). After week 3, an increasing growth rate was again manifested until week 6 (0.69 ± 0.11 %CL d^{-1}), highlighting the second molt stage. Although less pronounced and statistically not significant (ANOVA, Tukey's HSD, $P>0.05$), another carapace rigidity stage followed on week 7 as denoted by another zero average specific growth rate (Fig. 4-14). A slight increase initiated again on week 8 (0.12 ± 0.08 %CL d-1) that may have been the start of the 3rd molting cycle.

Specific growth rates in terms of %BW d^{-1} showed a generally decreasing trend, from an overall mean of 3.47 ± 0.12 %BW d^{-1} during the first week to only 0.63 ± 0.24 %BW d^{-1} during the last week (Table 4-2). Generally, no significant differences in BW-SGR were found among treatments and control throughout the study period.

4.3.5.3. Shrimp's survival

The small initial size (mean CL±s.e., 8.42 ± 0.1 mm; mean BW±s.e., 3.4 ± 0.02 mg) of shrimp juveniles was a challenge for tagging. As a result, high immediate mortality was observed especially for staining and t-bar tagging during the practice runs as a direct effect of mishandling. However, tagging efficiency greatly increased after familiarization of the tagging procedure. During the actual experiment, immediate mortality was very low (1 to 3 individuals).

Survival steadily declined and was not significantly different (ANOVA, $P>0.05$) among treatments up to week 5 (control, 84%; staining, 73%; uropod trimming, 71%; T-bar tagging, 67%) (Fig. 4-15). The decrease in survival continued with similar trend until week 8 for control (58%), staining (60%, and uropod

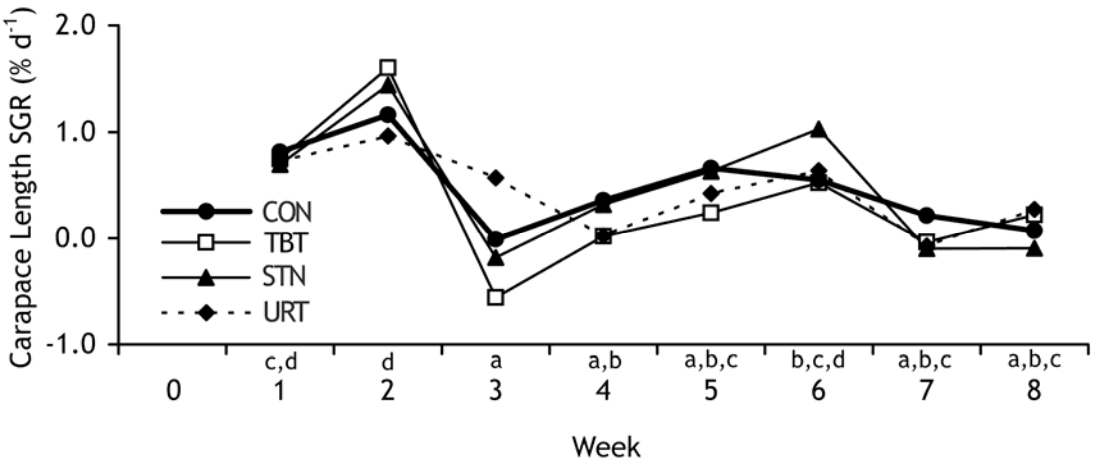

Figure 4-14. Specific growth rates (SGR) in terms of carapace length (%CL d^{-1}) of 2-mo old *Penaeus monodon* juveniles marked through staining (STN), T-bar tagging (TBT), and uropod trimming (URT) together with untagged control (CON) within 8 weeks. Molting periods are shown, terminating during the carapace rigidity stages (zero growth) at weeks 3, then week 7. Similar superscripts among weeks are not significantly different (ANOVA, P>0.05). Also, values among marking methods were not found to be significantly different.

Table 4-2. Specific growth rate (SGR) in terms of BW (mean ± s.e., %BW d^{-1}) of 2-mo old *Penaeus monodon* juveniles marked through staining (STN), T-bar tagging (TBT), and uropod trimming (URT), including untagged control (CON) within 8 weeks.

Week	CON	STN	URT	TBT
1	3.45 ± 0.38	3.72 ± 0.73	3.57 ± 0.34	3.14 ± 0.52
2	1.80 ± 0.24	0.58 ± 0.45	3.41 ± 0.26	1.43 ± 0.22
3	2.75 ± 0.35	2.28 ± 0.29	1.44 ± 0.22	2.07 ± 0.38
4	1.48 ± 0.27	0.58 ± 0.49	2.23 ± 0.72	2.50 ± 0.28
5	1.37 ± 0.30	0.82 ± 1.12	0.35 ± 0.57	1.01 ± 0.68
6	0.42 ± 0.46	-0.51 ± 0.73	1.17 ± 0.92	1.50 ± 0.18
7	0.73 ± 0.46	-0.79 ± 1.00	0.83 ± 0.33	-0.49 ± 0.45
8	0.75 ± 0.33	1.02 ± 0.47	-0.08 ± 1.04	0.82 ± 0.23

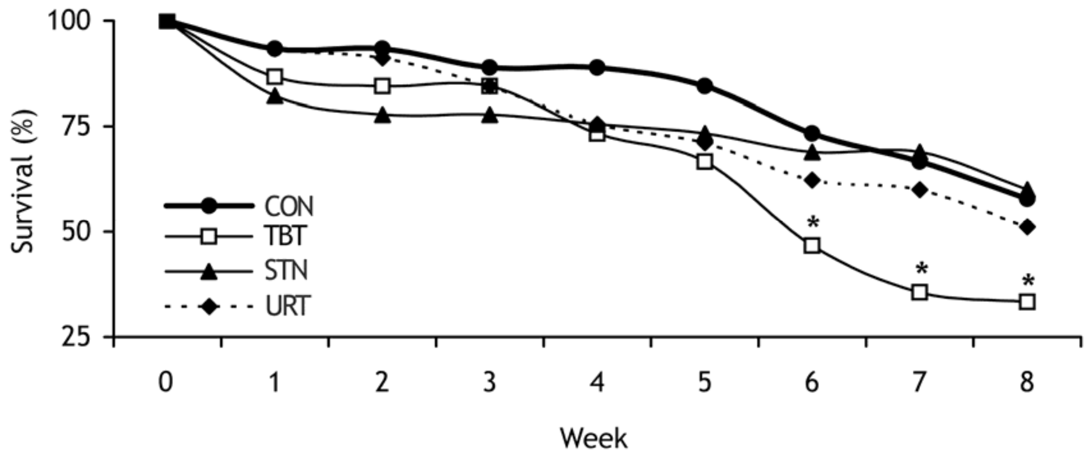

Figure 4-15. Survival (%) of *Penaeus monodon* juveniles marked through staining (STN), T-bar tagging (TBT), and uropod trimming (URT), including untagged control (CON) within 8 weeks. Asterisk (*) denote significant difference from among other treatments in the same monitoring week (ANOVA, P<0.05).

trimming (51%). However, T-bar tagging showed significantly lower (ANOVA, Tukey's HSD, P<0.05) survival rates of shrimps from week 6 (47%) until week 8 (33%).

4.3.5.4. Marker retention

Marker retention from survived shrimps was significantly highest (ANOVA, Tukey's HSD, P<0.05) up to the last week for T-bar tags where 100% were retained throughout the 8-week experiment (Fig. 4-16). However, visibility of trimmed uropods steadily declined until 65% at the end of 8 weeks, while only 14% of stained shrimps were identified as having been marked after the first week and none showed signs of staining from week 3.

For uropod trimming, marker retention was determined through abnormal regrowth of the trimmed portion. The decline in marker visibility for this method was caused by normal regeneration of uropods after molting on some shrimps. In weeks 2 and 3, after the first molt, 88% of the survived shrimps (14 out of 15 individuals) showed identifiable abnormal uropod regrowths; while from week 4 until week 7 (after the second molt), only 75% of the 10 surviving shrimps from each aquarium retained abnormal uropod regrowth. Lastly, at week 8, only 65% were recognizable as having had a trimmed uropod.

On the other hand, staining showed very significantly lower (ANOVA, Tukey's HSD, P<0.01) marker retention rate than the other methods, even on the first week where only 14% of the survivors were able to retain the red food color stain, mostly in the gills. At week 2, only 3% were observed to have a tinge of red in their body. Then, from week 3 onwards, no identifiable stain marks were observable from the experimental subjects.

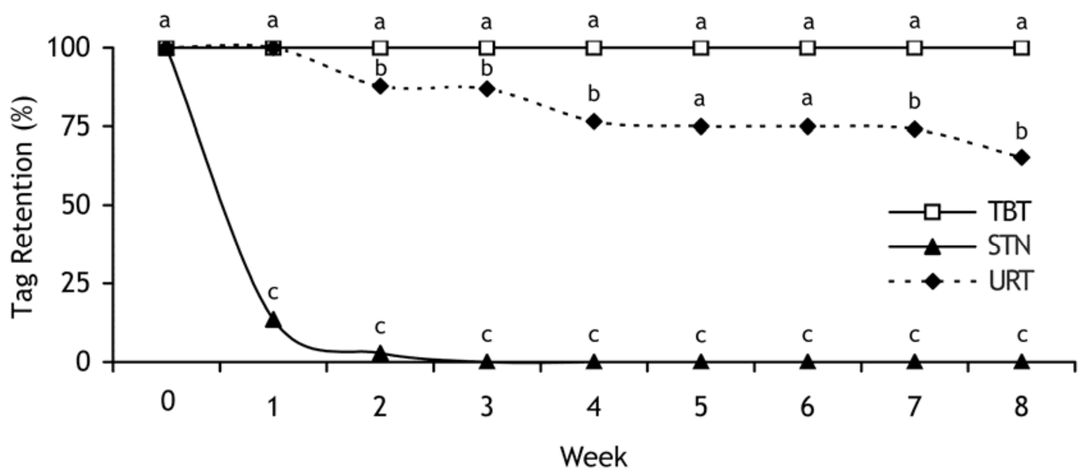

Figure 4-16. Tag retention/visibility (%) from survived *Penaeus monodon* juveniles marked through staining (STN), T-bar tagging (TBT), and uropod trimming (URT), including untagged control (CON) within 8 weeks of laboratory experiment. Similar superscript denote no significant difference among treatments in the same monitoring week (ANOVA, P>0.05).

4.3.4. Predation on shrimps

Simple seine dragging survey of fish population in the Isla Kapispisan site revealed mostly small fish sizes (Table 4-3). Similar with that of Thailand manrgoves (Ikejima et al. 2003; Tongnunui et al. 2002), Gobiidae and Leiognathidae species also dominated the site. Among the seven families identified, only the goby *Acentrogobius* sp. was known to feed on benthic crustaceans (Carpenter and Niem 2001), which may also include small shrimps. Benthic crustacean feeders commonly dominate mangrove areas (Nanjo et al. 2008). Other surveyed fishes were primarily detritus or zooplankton feeders. *Acentrogobius viridipunctatus*, *Leiognathus* sp., *Tetraodon* sp., and *Zenarchopterus buffonis* were caught irrespective of diel phase; while *Mugil cephalus* and *Hippichthys penicillus* were only caught during night tows, and *Ambassis* sp. were only caught during the day. The current survey only revealed a rather low diversity of fish in the area, therefore, a more comprehensive survey is recommended for future studies.

Actual fish assemblages within the site may have not been completely represented with the seine survey, where other more dynamic fish species may have escaped during the towing process. However, a secondary survey through tethering experiments further revealed additional shrimp predators. Tethering survey also confirmed that the spotted green goby *A. viridipunctatus* was indeed predating on juvenile shrimps where it was captured the most number of times (6 times) during the trials (Fig. 4-17). Two other species caught by tethering, but were not collected in the seine net survey, were the crescent perch *Therapon jarbua* and the estuary snake eel *Pisodonophis* sp., both captured 2 times. Mud crab *Scylla* sp. was also caught two times with the tether line. This result shows that *Scylla* species may also be active predators that feed on smaller shrimps. Predation of *Scylla serrata* was also

Table 4-3. Fish species collected during day and night seine tow ($50m^2$) within the Isla Kapispisan site.

Representative Species	Family	Local name	Food preference	Average count (n=3)		Size range (TL*, mm)	
				Day	Night	Day	Night
Acentrogobius viridipunctatus	Gobiidae	bagtis	benthic crustacean	4±1.5	4±2	42-125	64-140
Ambassis vachelli	Ambassidae		detritus	12±9.5		46-161	
Hippichthys penicillus	Syngnathidae	torotot	zooplankton		1		119
Leiognathus splendens	Leiognathidae	sapsap	zooplankton	12	42±37	52-70	32-165
Mugil cephalus	Mugilidae	gusao	detritus		1		102
Tetraodon nigroviridis	Tetraodontidae	butete	detritus	2	1	82-140	150
Zenarchopterus buffonis	Hemiramphidae	sigliw	detritus	4±1.7	9	87-122	133-162

* TL = total length

Therapon jarbua *Acentrogobius viridipunctatus* *Pisodonophis* sp.

Figure 4-17. Shrimp fish predators caught through live shrimp tethering.

investigated by Hill (1979) and reported that they hunt through contact chemoreception especially at night and prefer smaller crustaceans like crabs and also molluscs like bivalves. This method may not quantitatively account for all preyed shrimps and all respective predators, but the evidence that clearly showed the hooked predator from the tethered shrimp is reliable.

Acentrogobius viridipunctatus was the fish predator of choice for the laboratory experiment on shrimp predation, based on previously mentioned results. Just for a point of comparison, the shrimp predator *Therapon jarbua* was also considered to be used in the experiment. However, because there was difficulty in collecting enough samples of *T. jarbua* from our particular site because it is naturally not among the dominant species (Table 3-2), the present experiment instead used *Lutjanus argentimaculatus* where enough was available from local fish cage farms. This same species was also used in a similar experiment on *P. monodon* predation by Primavera (1997).

In order to simulate actual mangrove areas into this microcosm sub-study, survey of natural mangrove root density was conducted and showed an average *Rhizophora* prop root density of 45±2.7 roots m^{-2}, while *Sonneratia* pneumatophore density was 141±19.1 roots m^{-2}. These values were used in setting up the microcosm experimental aquaria for shrimp predation.

Results of this initial experiment showed that there was no significant difference on predation rates among treatment habitats for both predator fishes *A. viridipunctatus* and *L. argentimaculatus*, although there was a significant difference between predators (*t*-test, $P<0.05$) (Table 4-4). After six hours, all shrimps survived and were not predated upon by the goby *A. viridipunctatus*. Continued monitoring even showed that 100% of shrimps still survived after 24 hours. The survival of all shrimps in this experiment does not mean a lack of predation activity. The sizes of experimental goby *A. viridipunctatus* (13.3-15.1 cm total length) were enough to even engulf the small *P. monodon* juveniles (5-6 mm CL) as was revealed in initial tests where other goby samples were placed in a test aquarium with some juvenile shrimps. To even increase chances of predation, the gobies were also starved for about two days and density of shrimps was more (12 m^{-2}) than the natural density (<2 m^{-2}). It was observed that goby did seek out for food and changed locations inside the aquaria. Attempts of predation were also observed many times though the shrimps flicked quickly and escape. After an attempt, however, the goby did not immediately hunt for the prey and tented to settle in place until the next opportunity came. It is interesting to note, however, that the field tethering survey, mentioned earlier, showed higher predation by gobies. The relatively abundant population of gobies in the natural environment increases the chances for the tethered shrimps to be predated upon. It can be said that gobies are active but rather non-persistent predators of shrimps; the presence or absence of structures like mangrove roots may not be that significant for this species.

On the other hand, although not significantly different (ANOVA, P>0.05), higher predation by snapper *L. argentimaculatus* on juvenile shrimps was recorded in treatments with mangrove structures (whether *Sonneratia* pnuematophores or *Rhizophora* prop roots) compared with bare substrate. Contrary to usual speculations, this preliminary experiment showed higher survival of shrimps in bare substrate (35%) compared with *Sonneratia* (25%) and *Rhizophora* (15%) treatments (Table 4-4). It was observed that snappers were more actively hunting for prey among mangrove structures, while snappers in the barren treatment tended to stay still. For further clarification, additional experiments are recommended for future work.

Table 4-4. Mean survival (%) of *P. monodon* juveniles from predation of goby *Acentrogobius viridipunctatus* and snapper *Lutjanus argentimaculatus* in three microcosm setup: barren substrate, *Rhizophora*, and *Sonneratia* areas.

	Barren substrate	*Rhizophora*	*Sonneratia*
After 6 hours:			
Goby	100	100	100
Snapper	35	25	15
P value (*t*-test, between predators)	0.030	0.051	0.001
After 24 hours:			
Goby	100	100	100
Snapper	n.d	n.d.	n.d.

The use of mangrove pneumatophores as shelter to escape fish predator by *P. monodon* was documented by Primavera (1997). In addition, *P. monodon* use these shelters often both during the day and night (Primavera and Lebata 1995). The results in the recent sub-study may be in irony with other studies and may not be statistically conclusive by itself, but this also proves that the predator-prey dynamics in mangrove and non-mangrove areas are complex. Primavera (1997) also mentioned that although many studies have been conducted on the "fish predator and shrimp as prey" theme, the generalizations on the refuge or anti-predation role of mangroves is difficult to make and that it is not only dependent on structure type and density but also on the behaviour of predator and prey.

Interestingly, the above observation where predation, on shrimps was higher in mangrove areas, was supported by another sub-study on field shrimp tethering. Results showed that the *Sonneratia* mangrove area offered significantly (ANOVA and Scheffe, $P<0.05$) lower survival rate for shrimps than the bare substrate area during the night (Table 4-5, Table 4-6, Fig. 4-18). There was no significant difference between *Sonneratia* and *Rhizophora* areas, or between *Rhizophora* and bare substrate areas (Table 4-6). Figure 4-18 also shows a decline in shrimps survival through time. The x-intercepts of each curve revealed that shrimps would eventually be totally predated upon after 185 min in both *Rhizophora* ($R^2=0.928$) and bare substrate ($R^2=0.980$) areas, while it would only require 130 min in the *Sonneratia* area ($R^2=0.930$). This result appeared contradictory to expected ideas that shrimps should have higher chances of survival in mangrove areas because of available structures for shelter. However, it was also well documented that fish density and abundance are also much higher in mangrove areas than open and barren substrates (Chong et al. 1990; Laegdsgaard and Johnson 2001; Shinnaka et al. 2008).

Table 4-5. Two-way ANOVA of survival of shrimp juveniles during the **night time** field tethering experiment at three habitat treatments (barren, *Rhizophora*, *Sonneratia*) at varying time (every 15 min after tethering for 120 min).

Source	SS (Type III)	df	MS	F	P
Corrected Model	3.600	23	.157	4.846	<0.001
Intercept	12.816	1	12.816	396.805	<0.001
habitat	.234	2	.117	3.616	0.031
time	3.333	7	.476	14.740	<0.001
habitat * time	.034	14	.002	.075	1.000
Error	3.101	96	.032		
Total	19.517	120			
Corrected Total	6.701	119			

Data are log-transformed.

Table 4-6. Significant groupings with Scheffe' test (P<0.05) among habitats during the night time tethering experiment.

Habitat	n	Significant groups*	
Sonneratia	40	1	
Rhizophora	40	1	2
Bare substrate	40		2

* Similar group number denotes no significant difference.

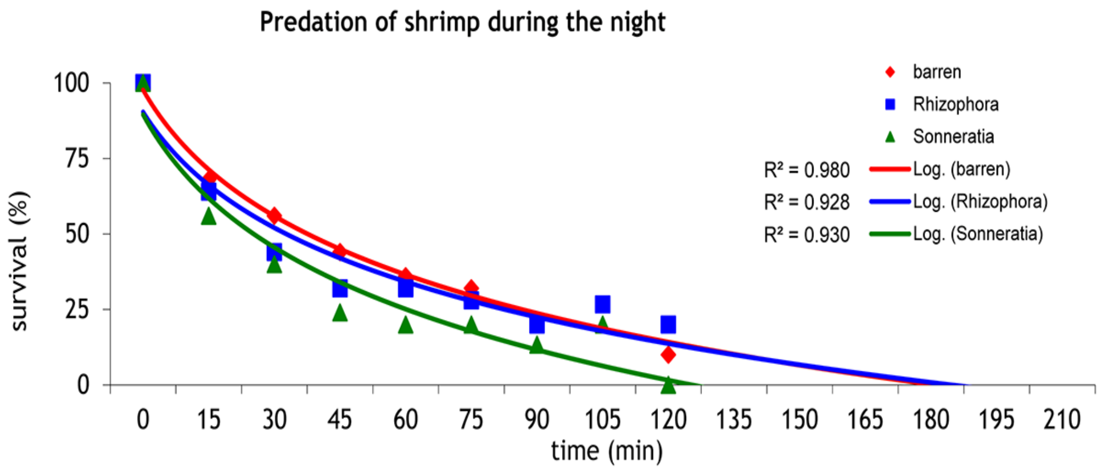

Figure 4-18. Mean survival of shrimp juveniles from night time tethering experiment in a bare substrate area, *Rhizophora* area, and *Sonneratia* area (n=7).

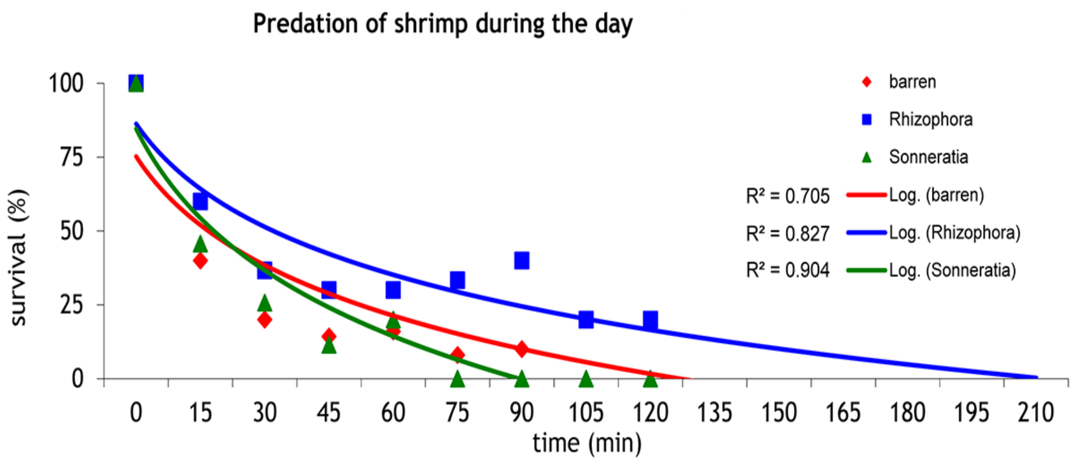

Figure 4-19. Mean survival of shrimp juveniles from day time tethering experiment in a bare substrate area, *Rhizophora* area, and *Sonneratia* area (n=7).

Moreover, fish communities prefer the pneumatophore (*Avicennia*) microhabitats than the prop root (*Rhizophora*) habitats (Ronnback et al. 1999). This abundance of fish in mangrove areas logically translates to more predator fishes for shrimps, hence the high predation mortality of shrimps in the current *Sonneratia* pnuematophore area than *Rhizophora* area or bare substrate area; although no actual comparative survey of fish assemblage was done for this study. Aside from this natural abundance of predators in areas with structures like mangrove roots, they may also be more actively hunting in these environments than barren areas. This was observed in both the tethering and the aquarium experiments in this study.

It was also observed that feeding of fish was more commonly during the night. Shrimps such as *P. monodon* are also known to be actively moving and feeding at night and mostly burrow during the day (Primavera and Lebata, 1995). Diel phases of day and night tethering were also found to be highly significant (Table 4-7). Survival of shrimps was significantly higher at the *Rhizophora* area compared to *Sonneratia* and bare substrate areas (Table 4-8, Table 4-9). Regression curves indicate that shrimps in the *Rhizophora* area (R^2=0.827) have longer survival possibilities during the day (210 min) than at night (185 min) (Fig. 4-19). However, shrimps at bare substrate area (R^2=0.705) and *Sonneratia* area (R^2=0.904) have lesser chances of survival during the day, with only 128 min and 90 min, respectively. In support of this, a study by Ronnback et al. (1999) in a natural mangrove area in the Philippines showed that shrimp density was really higher in *Rhizophora* (prop roots) area than *Avicennia* (pneumatophores) area. Whether these observations are results of predator avoidance or nursing behaviour, the value of *Rhizophora* mangroves in harbouring greater number of shrimps (at least during the day), has big implications in terms of mangrove reforestation and conservation in the Batan Estuary.

Table 4-7. Three-way ANOVA of survival of shrimp juveniles in the field tethering experiment at three habitat treatments (barren, *Rhizophora*, *Sonneratia*), two diel phases (day and night), at varying time (every 15 min after tethering for 120 min).

Source	SS (Type III)	df	MS	F	P
Corrected Model	8.803	47	.187	5.589	<0.001
Intercept	16.507	1	16.507	492.560	<0.001
diel	1.501	1	1.501	44.788	<0.001
habitat	.394	2	.197	5.874	0.003
time	6.286	7	.898	26.795	<0.001
diel * habitat	.179	2	.089	2.667	0.072
diel * time	.221	7	.032	.943	0.474
habitat * time	.151	14	.011	.322	0.991
diel * habitat * time	.063	14	.004	.134	1.000
Error	7.239	216	.034		
Total	31.786	264			
Corrected Total	16.042	263			

Data are log-transformed.

Table 4-8. Two-way ANOVA of survival of shrimp juveniles during the **daytime** field tethering experiment at three habitat treatments (barren, *Rhizophora*, *Sonneratia*) at varying time (every 15 min after tethering for 120 min).

Source	SS (Type III)	df	MS	F	P
Corrected Model	3.702	23	.161	4.668	<0.001
Intercept	4.429	1	4.429	128.439	<0.001
habitat	.349	2	.175	5.066	0.008
time	3.158	7	.451	13.085	<0.001
habitat * time	.194	14	.014	.403	0.972
Error	4.138	120	.034		
Total	12.269	144			
Corrected Total	7.840	143			

Data are log-transformed.

Table 4-9. Significant groupings with Scheffe' test (P<0.05) among habitats during the day time tethering experiment.

Habitat	n	Significant groups*	
Sonneratia	48	1	
Bare substrate	48	1	
Rhizophora	48		2

* Similar group number denotes no significant difference.

4.4. Chapter Summary and Conclusion

It is the decline in wild population of tiger shrimps in the Batan Estuary that the prospect of its stock enhancement in the area was entertained. Shrimp stock enhancement programs in other countries were mainly focused on ecological, scientific, or commercial implications. However, a similar program in the Batan Estuary may as well be aimed to principally increase income for artisanal fishers. Related literature on stock enhancement highlights the need for evaluations specific to the area and target species. In this connection, some of these were addressed in this chapter through actual experimental studies on tiger shrimps done on-site. Important information on source of stocks, pre-release culture method, area of release, optimal age at release, practical shrimp marker and shrimp predation were covered here.

Hatchery-reared juveniles are much cheaper than wild sources and are thereby practical for the Batan Estuary where a number of shrimp hatcheries still operate along nearby coasts. Based on site assessments, upper river areas are more conducive for juvenile shrimps, especially the 32-ha mangrove reserve site called the "*Isla Kapispisan*" that can provide good habitat and protection for juvenile shrimps.

Field experiments on natural mortality of shrimps showed that 2-mo old juveniles achieved optimum survival and growth when released in the *Isla Kapispisan* area. This suggests that shrimp larvae need to be reared until about 60-d old prior to release. In a separate study, two rearing options were compared: enclosed pond and open-area net enclosures at the release site. Growth and survival of shrimps were significantly higher by 50% and 20%, respectively, in ponds than in open area. Also, pond operation was more convenient, being minimally affected by tides, flooding and wind compared to the open. However, unlike pond rearing, open-area culture does not require additional expense for transport of stocks during release time because nets can simply be opened. Also, cultured juveniles can already be adapted, being acclimated in the open area during the whole culture period. This can be further confirmed through pilot stocking activities with assessments and monitoring of released stocks.

One important component of stock enhancement monitoring is marking or tagging of stocks. For this purpose, three low-cost marking methods (staining with food color, uropod trimming, and T-bar tagging) were tested in this study. Food color stain was proven to be a poor shrimp marker because its retention was limited to a week at most. T-bar tags are not effective markers despite having excellent tag retention because of low shrimp survival after 6 weeks. Uropod trimming is a more practical option because shrimps showed comparable survival and growth with the control group and marker distinction through unique uropod regrowth was high.

Natural predation on shrimps was also assessed through laboratory and field experiments. Although gobies *Acentrogobius viridipunctatus* were abundant, their predation on shrimps was more lax, compared with more aggressive predators like *Lutjanus argentimaculatus*. Mud crabs such as *Scylla serrata* were also abundant in the mangrove areas and have been found to feed on shrimps. Both mangrove and barren areas showed high shrimp predation during the night, but day-time survival of shrimps was higher in *Rhizophora* areas. This suggests that releasing shrimp juveniles at day-time in *Rhizophora* areas may possibly provide higher chances of survival for shrimps, although additional studies are recommended to further support this idea.

Additional studies were also planned for this project, including a pilot small-scale release experiment. However, due to unfavorable circumstances like a series of typhoons hitting the study site in the past years, the implementation of the trials was hampered. In addition, other important sub-studies were consequently postponed as caused by these unforeseen delays..

CHAPTER 5

GENERAL SYNTHESIS AND CONCLUSION

CHAPTER 5

GENERAL SYNTHESIS AND CONCLUSION

5.1. Decades of change in the Batan Estuary

In the Philippines, being an archipelago of 7,107 islands, coastal zones are considered to be the most important areas for residence and livelihood, especially for more than half of the country's 90 M people living in the rural areas. The Batan Estuary in the northern coast of Panay Island in central Philippines exemplifies a typical rural coast – with various resources and various conflicts. This 2,700 ha semi-enclosed estuary is being shared mainly by three municipalities (Altavas, Batan, and New Washington) of Aklan Province, 29 coastal villages, and some 90,000 people.

The Batan Estuary was once noted to be a very productive fishing ground with lush mangrove forests and active wildlife (Altamirano 2007). However, the area now has seemingly been undergoing a degenerative phase, suffering from degrading estuarine environment and brackishwater fisheries.

Mangrove forests were reduced by 92% in in less than half a century. According to the National Mapping Authority of the Philippines, the Batan Estuary had some 4,800 ha of lush mangrove forests in 1953. It is viewed that the rapid development of culture ponds served as the major cause of this decline where 3,747 ha of ponds on left the estuary with some 409 ha of scattered mangrove patches. Most are even just thin strips of replanted *Rhizophora* along dikes for protection. Nevertheless, driven by poor fisheries, some people still resort to illegal conversion of the remaining mangroves or reclaiming riverbanks to build more ponds.

The worsening water condition has become obvious, as well as the more restricted water flow and shoaling of rivers. Mean shoaling was found to be 1.5±0.2 m from 1979 or about 5.3 cm yr^{-1}.

Changes in inshore fisheries were similarly striking. Catch-per-unit-effort (CPUE) in terms of total daily catch per stationary stake net ($kg \cdot gear^{-1} \cdot d^{-1}$) was about 24 kg in 1970s. This was reduced to 10 kg in 1980s and to only about 5 kg in 2000. Others showed a decrease from 7.66 $kg \cdot gear^{-1} \cdot d^{-1}$ in 1990 (Ingles et al. 1992) to only 3.44 $kg \cdot gear^{-1} \cdot d^{-1}$ in 2000 (Babaran et al., 2000). Results in this study further showed that current CPUE was only 1.65 $kg \cdot gear^{-1} \cdot d^{-1}$. Shrimp fisheries, the most important livelihood, declined in quality and quantity where the highly-priced and once abundant tiger shrimp *Penaeus monodon* was replaced with smaller-sized and lower-priced species. Based on actual catch survey for stake nets in 2006, shrimp catch (mostly *Metapenaeus ensis*) averaged 0.7 $kg \cdot gear^{-1} \cdot d^{-1}$, composed primarily (70%) of small juveniles of less than 20mm carapace length. Local fishers, who recalled catching about 6 kg of tiger shrimps per day in the 70s, were disappointed to catch literally nothing of the species at present. Lacking efficient fisheries guidelines, local fishers desperately attempted to increase catch by multiplying the number of gears.

In every decade since 1970s, population in the area has been increasing by 10-20% but artisanal fisheries production, most importantly for shrimps, has been declining by 50%. Desperate to increase income to feed an average family of 8, fishers intensified fishing effort by multiplying their fishing gears, reaching 400% more than 15 years ago, only to obtain a mere ¥200 per day.

According to some reports and government office records, a number of fisheries and resource management programs have already been implemented in the Batan Estuary. However, most of these programs were grants and aids that usually only has short term effects and no observable long-term sustainability. The "top-down" nature of these programs sometimes fails to reach down into the root or base of problems. When funds become exhausted and activities slow down, the people still tend to return to what they were used to do.

The development of aquaculture in the 1970s significantly increased the total fisheries production. This was a big achievement in terms of economics but in a social perspective, majority of the people were more impoverished. Wide aquaculture farms are owned by rich people who may not even be local residents. Therefore, the bulk of the benefits from aquaculture were only converted to profits of a few rich families. The construction of ponds has left the natural ecosystem at a state of unrecoverable degradation robbing the poor fishers of their wild fish resources. Many noticed that after the mangroves were cleared and aquaculture farms constructed, wild population of fish and shrimps decreased. In effect, the majority of the human population dependent upon wild capture fisheries were in a worse condition. Driven by poverty and desperation to survive, some fishers engage in illegal fishing practices like the use of small meshed nets and fish poisoning. Others even committed crimes like theft of other people's fishing gears and catch. Such crimes and other even greater felony have been said to have become more frequent in the area.

The Batan Estuary has indeed changed and if the current trends continue, this negative alteration is also expected to persist. Although other management approaches were tested and various laws are in place, the environmental and fisheries problems in this coastal zone seem to worsen. The lack of political will, weak law enforcement and inconsistent cooperation among communities, obscure the view of improvement. It is perhaps time to, yet again, change this rural coastal zone. But this time, the change needs to begin with the people themselves.

5.2. Main concerns in the Batan Estuary

Interview surveys revealed that fishers and communities were well aware of the threats they are facing in the Batan Estuary. They outlined many problems that were generalized into (1) small income caused by poor catch and overcrowded fishing gears; (2) degraded environment with hardly any mangroves, shallow water with heavy siltation; and (3) poor law enforcement.

Based on results from previous chapters, the main problems in the Batan Estuary can be summarized into three main points:

1) the poverty situation among local fishers is worsening due to low quality and quantity of catch, especially of shrimps;

2) the intense overfishing in the area is evident with overcrowded fishing gears, and the use of illegal fishing methods; and

3) the natural environment was extremely degraded where 92% of mangroves were lost, mostly to aquaculture ponds.

With the concerns given, it follows logically that the direct solutions to these problems are:

1) to increase fishers' income;

2) to reduce the number of fishing gears; and

3) to rehabilitate mangroves

It is with these ideas that shrimp stock enhancement plays crucial roles, which are discussed in the succeeding sections.

5.3. Roles of shrimp stock enhancement in the Batan Estuary

Although fish stock enhancement programs have been done since the late 1800s, shrimp restocking initiatives however, still remain limited. So far, only seven major shrimp release programs have been implemented, mostly in developed countries like Japan, U.S.A., China and Australia (Bell et al. 2005). The purpose of these release programs was mainly geared towards gains in big-scale commercial fishing and gaming industry, environmental conservation, and scientific advancement (Hamasaki 2006; Bell et al. 2006; Wang et al. 2006; Loneragan 2006). However, in developing countries like the Philippines where poverty is prevalent especially in rural coastal communities, the focus of such projects is mainly on poverty alleviation. The need of artisanal and subsistence fishers to have better harvest is a major consideration to alleviate their lives and livelihood to better support their family. Based on previous discussions, aside from increasing fishing harvest of fishers, it is also important to reduce fishing structures and reforest mangroves as first steps to ultimately rehabilitate the Batan Estuary. However, these drastic changes directly affect the fishers and may seem to demand sacrificing their only means of livelihood. This section presents the prospects and challenges of tiger shrimp *P. monodon* stock enhancement as a “positive reinforcement” towards the rehabilitation of the Batan Estuary.

5.3.1. Increase fisher’s income

Based on actual catch data, fishers only harvest about 700 g of shrimp per gear daily equating to ₱ 34 (Philippine Peso) (Table 5-1). This is almost totally composed on *Metapenaeus ensis*, which only commands a lower market value. Although one household is only legally allowed two fixed fishing gears, others were observed to have more than 5 units. Assuming that one fishing household has 5 fishing gears, this would equate to a daily total catch of 3.5 kg or about ₱ 170. This value is still below the ₱ 193 minimum daily wage designated for agriculture and fisheries in this region (National Wages Commission, Philippines, 2008).

Interestingly, during heavy rains, some dikes of aquaculture shrimp ponds collapse and release cultured shrimps out to the rivers. Consequently, fishers noted unusual high catch of tiger shrimps at these times, thereby boosting their profits temporarily. This prospect of artificially introducing shrimp stocks is viewed to be a viable technique in increasing income of fishers. A more controlled release incident is already a simple shrimp stock enhancement activity.

Table 5-1 also shows hypothetical catch per gear scenarios for *P. monodon*. This is based on a hypothetical recovery rate of 2% from a release of 500,000 juveniles, harvested by 330 active fishers within the northern Batan Estuary. With effective fishery rules and enforcement, Scenario 1 shows that catching about 30 pcs (375 g) of *P. monodon* in the 2-3 cm CL size class can already provide ₱ 105. Based on data on experiments in this study, to reach this size would require a pre-release culture period of about 2 months. In Scenario 2 with a culture period of 3 months, allowing larger shrimp sizes of around 3-4 cm CL, even only harvesting 12 pcs can already produce the same weight (350 g) and equivalent sales (₱ 105) with that in Scenario 1. Both scenarios clearly show almost 3 times as much gain as compared to the present situation. The principle in this theory is very basic, that is, to increase the income of fishers by providing a much more expensive commodity. So, even if they capture lesser number of shrimps, they still would have a net gain compared to their usual low-priced harvest.

Table 5-1. Actual (*M. ensis*) and hypothetical (*P. monodon*) daily catch per fish corral in the Batan Estuary.

Metapenaeus ensis (recent actual catch)			***Penaeus monodon*** (hypothetical catch after re-stocking)			
Shrimp Size (CL, BW)	Price (₱ $\cdot kg^{-1}$)	Ave. daily catch (pcs.) wt., sales	Shrimp Size (CL, BW)	Price (₱ $\cdot kg^{-1}$)	Scenario 1 (pcs.) wt., price	Scenario 2 (pcs.) wt., price
>4cm, >10g	150	(5) 50 g, ₱ 8	3-4cm, 15-35g	300		(12) 350 g, ₱ 105
2-4cm, 3-8g	80	(25) 150 g, ₱ 12	2-3cm, 5-15g	150	(30) 375g, ₱ 105	
1-2cm, 1-4g	40	(80) 250 g, ₱ 10	1-2cm, 1-5g	60		
<1cm, <1g	15	(230) 250 g, ₱ 4	<1cm, <1g	20		
TOTAL:		700g, **₱ 34**	TOTAL:		375g, **₱ 105**	350g, **₱ 105**

NOTE: Ph₱ 1=US$0.02=Jp¥2.3 (as of Sept. 2008)

5.3.2. Decrease number of fishing gears

With the same scenarios above, where *P. monodon* catches can provide about ₱ 105, the positive effect on minimizing fishing gears is clear. Given that actual current catch only provide ₱34 per fishing gear, one household therefore require 6 fishing gears to meet the ₱ 193 minimum daily wage designated for the area. This is also the main reason why some fishing households choose to illegally own more than the allowed two fishing gears in order to support the needs of their large family size. However, being able to gain ₱ 105 per gear with *P. monodon* catches would only require 2 fishing gears to have a total sales of ₱ 210, which is already more than the minimum income level. Of course, additional income can also be accumulated from catches of other shrimp species, crabs and fish.

Therefore, assuming that each family owns 5 gears to meet their family needs; through the release of *P. monodon,* the number of gears can be reduced to only 2 gears per household. This translates to a huge 60% reduction of gears, once properly encouraged and implemented.

5.3.3. Mangrove rehabilitaion

The importance of mangroves as habitat especially for shrimps has been well established (Sasekumar et al. 1992; Chong et al. 1996; Primavera 1998). It has also been established in the present study that *Rhizophora* area provides higher chances for shrimps to survive, especially during the day. Using this information, it is important to increase the awareness of local fishers and communities on the benefits of mangrove as habitat and nursery for fish and shrimps and eventually encourage mangrove conservation and reforestation, especially in abandoned ponds.

5.4. Requirements for shrimp stock enhancement in the Batan Estuary

Although it has been previously presented that the roles and prospects of *P. monodon* stock enhancement in the Batan Estuary are high, there are still a number of considerations before it can be actually implemented. Stock enhancement program requires knowledge of basic information that includes biology, ecology, and social aspects. Even the simple definition of purpose needs careful attention (Bell et al. 2006; 2008). Prior to restocking, site- and species-specific studies must be conducted first (Loneragan et al. 2006). Although all of these requirements were not covered in this limited paper, still, some basic information like source of stocks, pre-release culture method, optimal age at release, practical shrimp marking techniques, and natural shrimp mortality were preliminarily addressed in this research through on site experimental studies on tiger shrimps.

5.4.1. "Restocking" or "stock enhancement"?

It has been pointed out that at the initial stage of planning for release programs, the definition of the nature and purpose of such an activity is important. As discussed here in Chapter 1, there are various concepts relating of a seemingly similar activity. Currently however, only two main concepts have been generally considered, namely: (1) *restocking*, that refers to the release of cultured juveniles to restore spawning biomass to levels where the fishery can once again support regular harvests; and (2) *stock enhancement*, referring to the release of cultured juveniles to overcome recruitment limitation (Bell et al. 2006; Loneragan et al. 2006). Considering these definitions, the concept of "stock enhancement" is more fitting to be applied in the Batan Estuary because the initial priority will be to increase stocks in order to enhance artisanal capture production of shrimps, thereby increasing the income of fishers.

Consequently, the “restocking” concept will be eventually pushed through in later stages, allowing the released stocks to reach reproductive maturity and ultimately enhance natural recruitment. However, this requires much more comprehensive studies and planning.

5.4.2. Penaeus monodon and the Batan Estuary

The once productive Batan Estuary in northern Panay Island has been steadily becoming worse in the past decades, where mangroves were lost, water level becoming shallower, and aquatic resources declining (Altamirano 2007; Altamirano and Kurokura 2009). Shrimps, in particular, considered as a major commodity in the area, have shown significant decline both in terms of quality and quantity (Ingles et al. 1992, Altamirano et al. 2009). Specifically, in the seventies, the highly priced tiger shrimp *Penaeus monodon* were observed to be abundant in the wild, but are now considered to be very rare (Motoh 1981; Altamirano and Kurokura 2010b). Other shrimp species like the greasy-back shrimp *Metapenaeus ensis* can still be caught in the wild, but these provide lesser income because of their smaller size and lower market value (Altamirano and Kurokura 2010b).

Motoh (1981) has done extensive work on the tiger shrimps *P. monodon* in the Batan Estuary in the late 1970s, and showed the abundance of wild broodstock in the area throughout the year. Natural wild seeds of tiger shrimps were also found all year round but peaks were observed to be around April to June. Fishers also mentioned the abundance of tiger shrimps three decades ago, where each fisher can catch up to 6 kg per day (Altamirano 2007). Although tiger shrimps only composed an average of 10% of the total number of shrimps caught in 1976-1978, these shared 40% in terms weight (Motoh 1981). Because of their larger size (captured then at an average of 82 g body weight), they were preferred over other shrimp species and gained the highest commercial value. Current shrimp catches, however, showed that *P. monodon* shrimps seem to have disappeared. These became even rarer, now only composing about 6.2% of catch by weight (Chapter 3, Fig. 3-10).

Since the tiger shrimps *P. monodon* were natively present in the Batan Estuary, the prospect of enhancing their wild population within these waters is high. Shrimp stock enhancement in this case, is not only advantageous in restoring wild population of tiger shrimps, but more importantly in enhancing catch and livelihood for fishers. It is an attractive idea that the re-introduction of this expensive species in the area can increase the fishing income of the local fishers.

5.4.3. Studies on P. monodon in the Batan Estuary

Results and findings on the studies conducted specific for the Batan Estuary can be summarized in a list as follows:

1. Source of stocks – Hatchery-reared juveniles are much cheaper than wild sources and are thereby practical for the Batan Estuary where a number of shrimp hatcheries still operate along nearby coasts.
2. Area of release – The *Isla Kapispisan* mangrove protected area in the upper rivers of the Batan Estuary may provide good habitat for shrimps
3. Optimal age for release – 2-mo old shrimp juveniles (~10 mm CL) may be the optimal age (or size) for release in the *Isla Kapispisan* area
4. Pre-release culture method – Pond culture still remain to be the more manageable option for pre-release rearing, although additional acclimation on site will be required prior to actual release.

5. Practical shrimp marker - Uropod trimming is a more practical option because shrimps showed comparable survival and growth with the control group and marker distinction through unique uropod regrowth was relatively high.

6. Fate of released shrimps – The Batan Estuary (*Isla Kapispisan*) showed high predation rates on shrimps in the wild, but *Rhizophora* areas may provide higher chances of protection; thus the importance of increasing mangrove cover in the area.

Additional studies were also planned for this study, including a pilot small-scale release experiment. However, due to unfavorable circumstances like a series of typhoons hitting the study site in the past years, the implementation of the trials was hampered. In addition, other important sub-studies were consequently postponed as caused by these unforeseen delays and insufficient time and funds.

It is also recommended that additional studies must be importantly considered and conducted in the area which may include, but not limited to:

1) Genetic introgressions – Broodstock must be carefully be chosen so as not to have drastic genetic impacts on wild populations.

2) Risk assessments – These includes not only the effects of genetic "pollution" in the area but also on the spread of diseases

3) Cost-benefit analysis – Especially for larger stock enhancement programs, a more thorough feasibility study and cost-benefit analysis must be made.

4) Bioeconomic assessments - These assessments are essential because it considers not only economic gains but also environmental concerns

5) Social impact – Ultimately, it is important to assess the effect of such programs to the direct beneficiaries who are the local communities

5.5. Concluding Remarks

Although there were projects implemented and various ordinances and laws exist in the Batan Estuary, the usual environmental and fisheries problems are still evident. The perceived weak law enforcement and political will, together with the feeble cooperation among leaders and local communities, further complicate the situation. With the observations and results above, it is clear that the Batan Estuary urgently needs effective measures for rehabilitation. One alternative fisheries and environmental management option suggested is through stock enhancement of the tiger shrimp *P. monodon* in the Batan Estuary. Theoretically, by restoring wild populations of this highly-priced shrimp species, fishers can directly increase income. With this incentive, reduction of fishing gears and mangrove rehabilitation can be promoted. The prospects of tiger shrimp stock enhancement in the area are high and the benefits are clear. However, some important points need to be considered prior to actual implementation of the program, based on established guidelines and recommendations discussed in this paper. Importantly, the support of sectors like the government, local universities, people's organizations, stakeholders, and local fishers must be solicited to create unbiased management plans.

This study has made some important scientific contributions, where there are currently only very few studies on stock enhancement specific for tiger shrimps *Penaeus monodon*. Basic concerns like source of stocks, rearing methods, optimal age of shrimps at release and practical tagging methods were determined, specifically for the Batan Estuary. However, many other necessary studies are yet to be conducted, following established guidelines, for an effective and responsible stock enhancement program. These include genetic considerations, health management, risk assessments, bio-economic modelling, and social impact studies. Although, the actual stock enhancement activity was not realized within the duration of this study (mainly caused by unforeseen circumstances like typhoons), the results and information gathered especially on the current status of the Batan Estuary, are crucial for future programs, management and legislations. It is an important recommendation in this study to consider a more social and community-based approach towards stock enhancement initiatives in the future. Moreover, other concerns like proper education, alternative livelihood, and community empowerment must also be similarly incorporated.

5.6. Recommendations

The research and surveys conducted for this dissertation was conducted in a rather short duration to cover every aspect of the Batan Estuary, its fisheries and to completely evaluate the prospects of shrimp stock enhancement in the area and conduct all the needed sub-studies. At least, however, the outcome and results of surveys and experiments conducted have shown the great potential for implementing a tiger shrimp *P. monodon* stock enhancement program. More importantly, the state of the degrading Batan Estuary was clearly presented, and the need for measures and management towards its rehabilitation is urgent.

Therefore, with reference to the observations and facts presented, the following general recommendations are suggested:

5.6.1. Mangrove conservation and rehabilitation

Mangroves are very important in maintaining populations of fish and shrimps, as established by many studies, including the results in the present study. These suggest a very practical need for mangrove rehabilitation to allow natural revival of wild fish and shrimp populations. The municipalities of Altavas, Batan and New Washington were already implementing mangrove rehabilitation projects. However, because of insufficient funds, weak political will, low technical training of staff, and absence of reliable scientific data, these projects remained unproductive. It has become customary for these projects to grow unsuitable species in inappropriate locations, ultimately ending unsuccessful. Planting of natural species like *Avicennia*, *Sonneratia*, *Bruguiera* and others must also be considered, rather than mono-plantation of *Rhizophora*. More importantly, planting in the rivers should be avoided. Rather, focus must be given on the rehabilitation of original mangrove areas which are now aquaculture ponds. This is already exemplified by the *Isla Kapispisan* mangrove reforestation area which originally was an abandoned pond. There must be a cooperative effort from the scientific community, government, and local communities to develop more effective management schemes to revive the Batan Estuary mangroves.

5.6.2. Reduction and regulation of stationary fishing gears

Based on interviews, local fishers themselves were aware of the over-crowded stationary structures in Batan Estuary. These do not only hasten overfishing, but also increase siltation, and limit navigation. It is evident that a considerable number of these structures have to be removed especially those that are non-operating or abandoned. It is also necessary to set unified rules among concerned municipalities to regulate the number of fishing gears operating in the whole estuary. This should include specific descriptions of allowed gears, standard licensing guidelines, and clear demarcation of fishing and navigation zones.

5.6.3. Efficient law enforcement, strong political will and people empowerment

The complicated political and social state of the Batan Estuary requires special considerations for improvement, such as strong cooperation between concerned parties and a set of unified guidelines for management. With unity among the three municipalities, confusion among conflicting rules can be avoided and simultaneous project implementation may be accomplished. However, this would require strong political will especially from local leaders, efficient law enforcement from the police and judiciary divisions, as well as active local people empowerment and participation.

5.6.4. Alternative livelihood for local fishers

Most of the resident fishers do not have other forms of livelihood. As population grew, demand for fish and shrimps increased and intense fishing pressure followed, as shown by the overcrowded fishing gears at present. Regulating the fishing activity in order to rehabilitate the estuary means to sacrifice the sole livelihood of fishers. Therefore, alternative livelihood aside from fishing must be introduced to alleviate the intense fishing pressure while providing stable income for the people. This may be in the form of employment in other industries, engaging in agriculture, or putting up some businesses. The government and other social institutions must be tapped for assistance in this matter.

5.6.5. Community-based shrimp stock enhancement

As discussed in this paper, release of *P. monodon* can be an effective tool to directly increase catch while providing such incentive for fishers to reduce their fishing gears and encourage mangrove rehabilitation. By artificially increasing wild populations of more expensive shrimps like the tiger shrimp *P. monodon*, fishers may be able to increase income even with less number of gears.

The direct effect and efficiency of shrimp stock enhancement to increase of natural stock is still not very well established because of difficulty in actual monitoring the impacts on catch. However, the effect of stock enhancement on the people is clear, as seen for example in the kuruma prawn *P. monodon* stock enhancement in Hamana Lake, Japan (personal information from Dr. Fushimi). The bottom-up approach focusing mainly on local fishers themselves has enriched their knowledge and education and encouraged active participation in the rearing and release phases of the program. In the case of Batan Estuary, there is an apparent weakness in the part of the government to effectively control and manage fishing activities. On the other hand, fishers themselves understand the problems in the Batan Estuary better than the managers and officials but they lack the power of control. Therefore it is better to implement a "bottom-up" approach in the area where local fishers are to be given main considerations. They should also be "participants" in the planning and implementing the stock enhancement program, with strong supervision from technical authorities. The clear-cut incentive of increasing income through higher sales from *P. monodon* catch is a strong motivation for the fishers to join the stock enhancement activity. During the course of this research, dialogues with local fishers in the Batan Estuary were done and their eagerness and willingness were genuinely manifested. They even formed a small core group of fishers and offered voluntary assistance, like monitoring and reporting their catch. With proper guidance and education through a bottom up scheme, local fishers will eventually be able to manage their resources and implement by themselves a sustainable *P. monodon* stock enhancement system in the Batan Estuary.

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