Proceedings of the Regional Technical Consultation on Stock Enhancement for Threatened Species of International Concern

Iloilo City, Philippines, 13-15 July 2005

Jurgenne H. Primavera, Emilia T. Quinitio and Ma. Rowena R. Eguia
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Cover photo collage (clockwise, from upper left)
Abalone (AC Fermin), Giant clam (SM Buen-Ursua), Giant catfish (Chiangrai Inland Fisheries Station, DOF, Thailand) and Seahorse (RBuendia)

FOREWORD

The SEAFDEC Aquaculture Department officially organized its Stock Enhancement Program in the year 2000, but its roots can be traced to AQD`s solid record in the seed production of various aquatic species, and its 10-year Community-Based Coastal Resource Management Project in Malalison Island, Antique, central Philippines. The Department`s achievements in maturation and breeding started with milkfish *Chanos chanos* and tiger prawn *Penaeus monodon*, but soon branched out to other species including seabass, grouper, siganid, snapper, seahorses, abalone, top shell, mud crabs and other invertebrates suitable for restocking.

Stock enhancement represents the interphase between culture and capture fisheries – seedstock reared in hatcheries-nurseries are released in natural waters, to be managed and eventually harvested by coastal communities. Unlike pond and pen/cage culture which require high capital investment, the growout portion of stock enhancement projects need very low financial outlay. Of prime importance is the effective protection of restocked juveniles (regulation of harvest sites, sizes, seasons) by local communities and governments, requiring adequate social organization and local governance. An added bonus from stock enhancement is environmental protection to provide healthy habitats, e.g., seagrass beds, coral reefs, and mangrove swamps where the released clams, shells, and crabs can survive and grow to marketable sizes. Moreover, the Revised Philippine Fisheries Code of 1998 requires local governments to set aside 15% of their territorial waters as protected areas, so stock enhancement can be part of a technology package to implement this pro-environment mandate.

Both the 1976 Kyoto Declaration on Aquaculture and the 2000 Bangkok Declaration on Strategy for Aquaculture Development underscored the potential of stock enhancement to increase fish supply from coastal and inland waters. Hence, AQD started a new Stock Enhancement Project in 2005 with support from the Government of Japan Trust Fund. In preparation for this project, the Regional Technical Consultation on Stock Enhancement was convened in Iloilo City last year. It is therefore with pride that I present the Proceedings of the Stock Enhancement Consultation.

Joebert D. Toledo, D. Agri.
Chief

September 2006

BACKGROUND

In April 2005, the Southeast Asian Fisheries Development Center (SEAFDEC) initiated the five-year Program on Stock Enhancement for Threatened Species of International Concern under the Government of Japan-Trust Fund. The main purpose of the Trust Fund is to ensure food security and reduce poverty, as set during the 2001 ASEAN-SEAFDEC "Fish for the People" Millennium Conference. The SEAFDEC Aquaculture Department (AQD) based in Iloilo, Philippines is tasked to implement the aquaculture-based component of this Program focused on stock enhancement, while the SEAFDEC Marine Fishery Resource Development and Management Department in Malaysia will cover marine turtles.

The SEAFDEC/AQD convened a Regional Technical Consultation on Stock Enhancement from 13 to 15 July 2005 in Iloilo City to identify suitable species in the region for stock enhancement, and to assess existing technologies for seed production, baseline surveys, release, and monitoring. Fifty-five participants from eight SEAFDEC Member Countries and from institutions active in stock enhancement attended the meeting (Appendix I). A total of 18 country and review papers provided status reports and scientific input for lively discussions during the concluding workshop. Future directions for the Program as recommended by the Workshop are embodied in the Resolution and Plan of Action that follow.

RESOLUTION

1. Stock enhancement should be undertaken as part of an integrated management strategy for sustainable use and conservation of aquatic resources.

2. Stock enhancement should be considered only if other interventions, such as reduction of fishing pressure and habitat protection or restoration, have proven inadequate.

3. Stock enhancement programs should use indigenous or native species to minimize adverse effects on ecosystems and biodiversity.

4. For species that are now used for stock enhancement programs in the Member Countries, technological support should be strengthened to ensure success.

5. Seed production technology for a species should be established before it can be considered for stock enhancement, but broodstocks may also be restocked to restore the breeding population.

6. As basis for evaluating the risks and benefits of stock enhancement, baseline surveys must be conducted before any release of stocks, to obtain physico-chemical, biological, and socioeconomic information, especially the characteristics of the receiving ecosystem and the stakeholder communities.

7. Hatchery-produced juveniles used for stock enhancement should be carefully screened for genetic makeup and health status to ensure that genetic diversity is conserved and only good quality juveniles are released.

8. Impacts of the stock enhancement activity should be monitored and evaluated on a regular basis, using the same methods and covering the same area or ecosystem as the baseline survey.

PLAN OF ACTION

SEAFDEC/AQD's Program of Stock Enhancement for Threatened Species of International Concern shall consist of three plans of action: (1) research and development, (2) technology verification, and (3) capability building.

1. Research and development will be conducted on species of international concern based on:

- List of species identified at the Regional Technical Consultation:

  a) Freshwater species
  Mekong giant catfish
  Pangasianodon gigas
  Arowana
  Scleropages formosus
  Giant Pangasius
  Pangasius sanitwongsei and *Pangasius larnaudii*
  Small scale mud carp
  Cirrhinus microlepis
  Mud carp or Chinese mud carp
  Cirrhinus molitorella

  b) Marine species
  Seahorses *Hippocampus* species
  Giant clams *Tridacna* species
  Donkey-ear abalone
  Haliotis asinina
  Sea cucumbers
  Holothuria species

- Regional concerns – common species and problem areas identified by the Member Countries will be given priority
- Technology gaps identified by each member country
- Available resources of the Program
- Mandate from the SEAFDEC Council

2. Appropriate technologies for stock enhancement will be verified:

- Technologies developed by AQD
- Technologies developed by Member Countries

3. The capability of the Member Countries for appropriate stock enhancement will be strengthened through training, study tours, publications, and dissemination of information regarding the following technical areas:

   - Planning and management of stock enhancement including review of existing activities
   - Site and resources assessment
   - Seed production (broodstock, hatchery, nursery)
   - Release strategies (including tagging and marking)
   - Monitoring and evaluation of impacts
   - Community-based management

Iloilo City, Philippines
16 July 2005

Participants of the RTC on Stock Enhancement for Threatened Species

1st Row (*from left*): T Sugaya, ED Gomez, JH Primavera, RR Platon, K Okuzawa, WG Yap, SD Silva

2nd Row: ET Quinitio, TU Bagarinao, MIJ Nievales, MRR Eguia, N Istiqomah, ACJ Vincent, TT Nguyen, NA Lopez, K Myo Win

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CONTENTS

Country Papers

ASEAN-SEAFDEC Directives Related to Species of International Concern

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Background

Over the years, policy makers and managers have been concerned about the manner and extent of current utilization of aquatic and fisheries resources. In Southeast Asia, overfishing coupled with conflicts among various users over the limited and degraded fisheries resources call for urgent action to rectify fisheries practices particularly through better management of aquatic resource utilization toward the goal of sustainable development. Stock enhancement as a management tool has become a regional challenge that requires greater attention.

In 1995, the Code of Conduct for Responsible Fisheries (CCRF) was adopted to provide norms and principles to guide the responsible utilization of fisheries resources. In support of the CCRF implementation by member states, the Food and Agriculture Organization (FAO) has developed supplemental International Plans of Action (IPOAs) and Strategies with the view of better addressing some priority issues such as fishing capacity, incidental catch of seabirds in longline fishing, sharks and illegal, unregulated and unreported (IUU) fishing (FAO 2005).

After a decade of implementation of the CCRF in 2005, some environmental groups increasingly claim that such implementation has achieved little progress and in many cases proved to be ineffective. They also claim that a substantial gap exists between commitment by the States and their actions. Alternatively, other initiatives/mechanisms (Convention on International Trade in Endangered Species of Wild Fauna and Flora or CITES, United Nations General Assembly, eco-labelling and trade barriers rather than FAO) have been promoted with the view of managing utilization of aquatic resources. These movements have brought grave concern to fisheries authorities at various levels as the initiatives/mechanisms are developed without considering the ongoing efforts of fisheries competence authorities that are working towards sustainable development and management of fisheries. In addition, concern has also been expressed regarding the competence and scientific bases of various fora and mechanisms that deal with the management of commercially important aquatic species. The recent outcome of the Thirteenth Conference of Parties (CoP13) of CITES (Vichitlekarn and Gamucci 2005) could be a good example of the above concern, which requires a closer investigation of lessons learned in order to set future directions for sustainable/responsible development of fisheries.

To support implementation of this global CCRF, the Southeast Asian Fisheries Development Center (SEAFDEC) initiated a Southeast Asian regionalization process of the CCRF in 1998. The objective of the regionalization was to address principles and issues of the CCRF taking into consideration regional specificity and requirements which had been overlooked during the preparation of the CCRF. After a series of consultations at national and regional levels, the regionalization process developed a set of regional guidelines for responsible fisheries in Southeast Asia including important thematic issues of fisheries namely, fishing operations, aquaculture, fisheries management, post-harvest practices and trade.

To follow up these efforts, the Association of Southeast Asian Nations (ASEAN) and SEAFDEC organized a Conference on Sustainable Fisheries for Food Security in the New Millennium: "Fish for the People" in 2001. With over 800 participants from Southeast Asia and around the world, the Conference discussed important fisheries and aquaculture issues and identified actions needed to achieve sustainable fisheries in Southeast Asia. As major outcomes of the Conference, the Resolution (RES) and Plan of Action (POA) on Sustainable Fisheries for Food Security for the ASEAN Region were developed under the framework and principles of the CCRF, and adopted by the ministers and their senior officials responsible for fisheries in region, respectively. The RES and POA are considered a regional policy framework and priority actions required to a) achieve sustainable development of fisheries and food security in countries of the region, and b) provide a regional framework for collaboration and partnership in fisheries.

ASEAN-SEAFDEC Directives related to Species of International Concern

To achieve sustainable fisheries for food security in the ASEAN region, the RES and POA urge the Member Countries to rectify their fisheries practices through improvement of existing fisheries management policy, framework and practices as well as implementation of the CCRF, RES and POA. Improvement of fisheries management includes the gradual introduction of decentralized rights-based fisheries and co-management systems, regulation/control of fishing activities, protection/rehabilitation of important aquatic resource habitats, resource/stock enhancement, and so on. In addition, the RES and POA also highlight the need to enhance partnership among Member Countries in the region through formulation of common positions as well as to increase their participation and involvement in international fora (FAO, CITES, etc.) to safeguard and promote ASEAN interests particularly on issues of international concern.

In line with the above general directives, especially in relation to stock enhancement of species under international concern, senior fisheries officials of ASEAN and SEAFDEC have urged proactive approaches in tackling the issues and gave the following directives:

1) To increase support to national initiatives and to facilitate regional cooperation on stock enhancement including identification of concerned species and their status, interaction between concerned species and fishing, and integrated approach and community involvement in management and conservation of aquatic resources;
2) To identify issues/species of international concern and conduct review on status of the issues/species as basis for formulation of fisheries policy as well as common positions among the Member Countries in international fora;
3) To compile information on status and initiatives related to management and conservation of aquatic resources and to disseminate them in appropriate international fora to enhance awareness of the regional situation and seriousness of the issues;
4) To promote appropriate inter-agency coordination on the issues at national and regional levels; and
5) To promote involvement of national fisheries agencies in national/regional/international fora/mechanisms related to utilization and management of aquatic resources.

Current regional programs supporting species of international concern

In response to the above directives, ASEAN and SEAFDEC jointly promoted a number of regional fisheries programs under the ASEAN-SEAFDEC Fisheries Consultative Group (FCG) mechanism established in 1999. The existing programs include:

Fish trade and environment

The program addresses close linkages between responsible trade in fish and fishery products and sustainable development of fisheries. Through its activities, the program conducts regular identification of trade-related issues, which have potential negative impacts on the fisheries sector in the region. Comprehensive reviews of the identified issues and their status will form the basis for the formulation of fisheries policy and common positions and the identification of strategies to address concerns among the Member Countries.

Management of fisheries and utilization of sharks in Southeast Asia

The program was initiated to support Member Countries in the implementation of the International Plan of Action on Management and Conservation of Sharks (IPOA-Shark). The program includes a one-year regional comprehensive study of shark resources, utilization and trade. Results of the study have provided a basis for dissemination of information on the current situation of sharks in the region, and future formulation and implementation of the National Plan of Action on Sharks (NPOA-Shark) by Member Countries in line with the IPOA.

It should be noted that utilization and management of sea cucumbers has been recently identified by the SEAFDEC Secretariat and will be soon formulated into a regional activity. Moreover, years of experience and expertise in stock enhancement of the Aquaculture Department (AQD) (for mollusks, seahorses, and other threatened aquatic species) and the Marine Fishery Resources Development and Management Department (MFRDMD) of SEAFDEC (for sea turtles) can provide a solid foundation for the implementation of the newly developed regional program on Research and Development of Stock Enhancement for Species of International Concern. The program is in fact a framework for this Regional Technical Consultation (RTC) on Stock Enhancement for Species of International Concern.

Issues to be Addressed on Stock Enhancement

Despite the fact that stock enhancement has been in practice in both inland and marine waters in the ASEAN region over the past number of years and the considerable progress and achievements made in this field, there are concerns on the goals and effectiveness of stock enhancement under the broad framework of sustainable management of fisheries resources. The following are issues that need due consideration when identifying future development directions of stock enhancement in the region:

- What are the goals of stock enhancement (religious/ceremonial, commercial, management)?
- Do stock enhancement programs contribute to higher fishery production in the region? In what context?
- Do the costs of stock enhancement outweigh the gains? Are gains sustainable?
- Can the same level of “enhancement” gained from hatchery releases be achieved through stronger fishing regulations and enforcement and/or habitat restoration?
- What are the explicit indicators of success? How they are measured?

- What other fishery management strategies need to be coupled with stock enhancement?
- What are the preconditions and responsible approaches and protocols of successful stock enhancement programs?
- What improvements need to be made in existing approaches?

Conclusion: The Way Forward!

With the view to support the Member Countries in achieving sustainable development of fisheries in the ASEAN region, it is timely for SEAFDEC/AQD to organize this RTC to address issues of stock enhancement particularly for species of international concern. The program on Research and Development of Stock Enhancement for Species of International Concern through this initial regional technical consultation could help monitor the status and progress of stock enhancement in the ASEAN region as well as clarify issues, context and future directions for stock enhancement of species of international concern. The program should be viewed as an opportunity to address this important topic in two general directions.

Support to national initiatives on stock enhancement

- Strengthening existing stock enhancement initiatives as effective management tools by mobilizing existing work and expertise among the Member Countries and SEAFDEC AQD;
- Developing a low-cost tool to illustrate positive impacts of stock enhancement on overall management of resource utilization;
- Identifying key factors and considerations based on stock enhancement experience to improve overall management of resource utilization; and
- Raising issues among policy-makers in appropriate fora to ensure support.

Support to the Member Countries on species of international concern in international fora

- Compiling and disseminating information on status of concerned species and seriousness of the Member Countries particularly on stock enhancement;
- Identifying potential international fora (including CoP14 in 2006) and assisting Member Countries in preparing their policy and common positions; and
- Coordinating with existing regional programs/initiatives including the ASEAN Expert Group on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (AEG-CITES) with regard to these issues.

Moreover, in promoting the above two directions, networking of regional experts on stock enhancement may be considered. Such networking not only facilitates improvement of national stock enhancement initiatives but also helps to identify species of international concern including their potential impacts on the fisheries sector in the region.

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Application of DNA-Based Markers in Stock Enhancement Programs

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Introduction

Aquaculture and fisheries management require tools for identifying individuals or groups of aquatic organisms for the purpose of monitoring performance (growth, survival and behavior) and stock structure. In aquaculture research, commercially important traits of tagged individuals are assessed to generate supportive data for selective breeding, genetic improvement and commercial-scale fish-farming. Fisheries management employs identification systems for the evaluation of stock abundance, population dynamics and documentation of wild and hatchery-bred stocks. Stock structure analysis is useful in the planning and implementation of sound stock management and more importantly, in stock enhancement programs. Blankenship and Leber (1995) underscored the inclusion of tagging/marking strategies for released hatchery stocks in the guidelines for responsible marine stock enhancement. Identifying and keeping track of introduced stocks in release habitats allows an assessment of their adaptability in the wild (Allendorf et al 1988) and the success of the reseeding and/or restocking effort.

Although often used interchangeably, the terms "tags" and "markers" differ by definition. Tags are artificial or synthetic materials that are attached to the aquatic organism to allow individual or group identification while markers are traits or characters either applied or inherent to the organism (Thorsteinsson 2002). Tags/markers are essential in evaluating resource distribution patterns, behavior, migration and movement of stocks, dynamics of exploited aquatic populations and evolutionary processes, all of which comprise baseline information for any stock management, enhancement and conservation program in aquaculture and fisheries (Allendorf et al 1988, Mulvey et al 1998).

Tags and Markers

Before choosing an ideal marker or tagging method, the program or research objectives should be clearly defined. The type of identification system should suit the purpose for which the tags are used. The species, size and number of organisms that will be tagged or marked, should also be known as some tags are size- and/or species-specific. Preliminary studies on the different types of identification techniques should be conducted to assess their performance and reliability. Through these preliminary trials, the preferred mode of attachment, duration of handling and effect of tagging on the identified organism can be determined. Tagging/marking should be done within a short period to avoid adverse effects on the tagged organism. Fouled tags and even the presence of some tagging/marking materials have been found to affect the health, behavior and growth of the identified animal (Thorsteinsson 2002). Finally, one should also take into account the cost of tagging/marking. A cost-benefit analysis should be conducted before finally deciding on a tagging/marking method that is cost-efficient and reliable.

Tag/marker types, advantages and limitations

There are four types of tags/markers used in fisheries research and these are – external tags, external markers, internal tags and internal markers (Thorsteinsson 2002, AFS et al 2004).

External tags

These are externally applied, visible tags which carry an individual and/or batch code (AFS et al 2004). Sometimes external tags also carry instructions on how recaptured organisms should be reported. Many of the conventional tags are classified as external tags. Examples are the ribbon, wire or spaghetti tags, Petersen disk and plates. Dangling tags (flag tags or Carlin tags), hydrostatic tags (anchor tags, floy T-bar tags and arrow tags), internal anchor tags, strap tags and jaw tags are also some examples of external tags. The internal anchor tag is a tag that is implanted in the body cavity of the animal but part of the tag hangs like a floy tag that is visible from the outside as well.

External tags are inexpensive and are therefore cost-effective. They are very detectable and can be applied to a large number, size and range of species. Apart from the number code, external tags also carry relevant reporting instructions. Many of these tags remain attached to the animal for a long period of time, hence the possibility of providing a large number of returns is high. External tags are ideal for providing information on broad geographical and seasonal return distribution.

Although the tags carry batch or individual code and reporting instructions, no data between release and recapture of the restocked individual can be obtained from the tags. Another disadvantage of the external tags is that their mere presence affects the animal, as reviewed by Thorsteinsson (2002). Long-term use can likewise expose the tag to fouling by macroalgae and attachment of other debris. Fouling makes the tag heavier, slowing down the movement of the animal. High tag loss or shedding is also possible due to fouling thus making this tagging method unreliable. Another limitation of external tags is that some may not be applicable to small animals.

External marks

External markers are external characters or modifications that are found on or applied to the organisms for identification purposes (AFS et al 2004). Some types of external marks have been used in studies related to taxonomy and systematics. Examples of these are the meristic (e.g., number of fin rays, spines, teeth) and morphometric characters (truss patterns, length measurements, scale shape, etc.). Some physical characters are modified and used as external marks. Fin-clipping, pinching and operculum punching are typical examples of these external marks. Pigments, dyes, stains and brands (hot and/or cold branding) are also used as external marks.

Like external tags, external marks are inexpensive, easy to apply and useful in identifying separate populations or groups. They can be applied to any species, size and number of organisms. Unlike external tags, external marks have little, if any, effect on the tagged organism. External marks can also have a long retention time depending on the type of marker used.

Although external marks allow batch identification, the number of marking combinations and codes may be limited. For marks like fin clips, the clipped fins regenerate later and could cause confusion in identifying or discriminating marked organisms. Some external markers, especially paints or dyes, may also deteriorate with time. Given the problems associated with external marks, recapture/return data from a broad geographical range may prove to be difficult.

Internal tags

These tags are injected or inserted into the body cavity, muscle or cartilage of aquatic organisms and are carried internally for individual or group identification (AFS et al 2004). Most of these tags require reading devices that will enable the detection of the implanted or inserted tags. Examples of these are coded wire tags (CWT), coded radio tags (CRT), coded acoustic tags (CAT), magnetic cavity tags, passive integrated transponder (PIT) tags, sonar transponding tags, transmitter tags, data storage tags (DST), and visible implant tags (VIT).

Internal tags allow individual identification and may be applied to any size and species of aquatic organism. They have a long retention time and have little effect on the growth, survival and behavior of tagged organisms. Likewise, repeated and non-destructive recoveries are possible. Using special fully automated equipment, a large number of individuals may be tagged at a single time.

Compared to external tags and marks, internal tags are costly. They require the use of detecting devices apart from trained people who apply the tags. Recovery of tagged specimens, retrieval and identification of the tags are labor intensive. Since the tags are kept inside the organism for a long time, tag migration within the organism is possible. As for some internal tags like VIT, the transparency of the tag may deteriorate through time. Moreover, internal tags do not carry sufficient information about the tagged organism.

Internal marks

Internal marks are marks that are either intrinsically found in the organism or are artificially produced (AFS et al 2004). These marks characterize the organisms individually or collectively. Chemical/thermal marks on otoliths and other bony structures as well as biological markers (e.g., type of parasites found on specific groups or individual aquatic organisms) are considered as internal markers. Other examples of internal marks are externally detectable elastomer marks that are injected into the organism. With the recent introduction of the polymerase chain reaction (PCR) technology and advances in molecular genetics, DNA-based genetic markers have been developed and used as internal markers.

Except for genetic markers, most of the internal marks are inexpensive, simple and readily applicable to a wide range of animal sizes. Some of the marks are visible for a long period and are repeatedly recognizable without causing any damage to the organism. Individual and group identification is possible with internal markers since one can use of a wide array of colors (especially for chemical marks) and marking positions.

Although internal markers keep for a longer period in the organism, the transparency of the marks may change through time, become less visible, and thus can be easily overlooked. In some cases, marker injection tools are required and special devices are necessary for marker detection.

Conventional markers like physical tags are commonly applicable in a) estimating growth in farmed and natural populations of aquatic organisms, b) evaluating survival, migration and behavior of restocked organisms, c) calculating recapture rates, d) comparing tag reliability and performance, and d) monitoring introductions, stock transfers and species conservation. These tagging/marking methods are efficient only when tagging losses and recovery errors are minimized. If tagging problems are not addressed, these methods might find limited use in population or stock structure analysis.

Genetic Markers

Traditional tags such as spaghetti and floy tags have been used for decades in both fish culture and stock management. Several types have evolved since then – from the very crude simple ribbon or wire tags to recent applications such as biochemical or genetic markers. Physical tags carry very limited information. More advanced markers such as genetic markers not only provide individual or batch identification, but also describe the genetic information of each marked individual and in general, the genetic structure and integrity of the stocks being monitored (Allendorf et al 1988, Ward and Grewe 1994, Mulvey et al 1998, Sweijd et al 2000).

Genetic markers are selectively neutral markers. They are biochemical attributes that remain as discrete character units or combinations of such units that are detectable as protein or deoxyribonucleic acid (DNA) variants (Benzie 1994). Genetic markers are indelible, present in all members of a population at all ages, and can be used to determine the source and relationships (parentage and kinship) among aquatic organisms (Pella and Milner 1987, O'Connell and Wright 1997). In this sense, genetic markers are unique and are able to discriminate between individuals and groups when traditional morphological differences are unclear (Sweijd et al 2000).

To fully understand what genetic markers are, we recall some basic concepts in genetics. Each cell in any organism contains chromosomes. Chromosomes are made up of long DNA molecules that are complexed with protein. Each DNA molecule has many genes that are the basic physical and functional units of heredity. A gene is a specific sequence of nucleotide bases (adenine, guanine, cytosine and thymine). Alleles are biochemically different forms of the gene while a locus is the specific location of a gene on the chromosome. The order of nucleotide bases along the sugar-phosphate backbone of DNA is referred to as the DNA sequence. Sequences carry information for constructing proteins that provide the structural components of cells, tissues and enzymes for essential biochemical reactions. Hence by definition, the DNA sequence specifies the exact genetic instructions for creating a particular organism each with its own unique set of traits. In developing DNA markers, DNA sequence information is a prerequisite. With the use of modern molecular genetics equipment like the PCR or thermal cycler, electrophoretic apparatus and DNA sequencer, DNA profiling and genetic marker development have been made possible.

Genetic markers can be classified into: a) maternally inherited mitochondrial DNA (mtDNA) markers, and b) biparentally inherited nuclear DNA markers. MtDNA sequence data and mtDNA-restriction fragment length polymorphism (mtDNA-RFLP) are classified as mtDNA markers while allozymes, randomly amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), and microsatellite DNA (msDNA) markers are nuclear DNA markers.

Two of the commonly used markers are mtDNA-RFLP and msDNA. MtDNA analysis is particularly useful for genetic marking as applied in gene conservation or the use of genetic information to measure and manage genetic diversity, and for molecular ecology (Moritz 1994). MsDNA markers are markers that follow a Mendelian codominant inheritance pattern (e.g., the two alleles in a gene pair, each associated with a different phenotypic substance or expression, appear together in a heterozygote). MsDNA markers are effective tools for the assessment of genetic divergence and pedigree analysis in the broodstock management of aquatic species (Taniguchi 2003). These two methods essentially follow similar protocols.

Genetic marker methods are non-invasive unlike physical tagging/marking. Molecular marker analysis can be carried out on fresh, frozen or alcohol-preserved tissue (e.g., scales, fin clips, pleopods) from the aquatic organism. Small tissue samples (from at least 30 individuals per stock) are collected and preserved. DNA extracted from each sample are PCR amplified using a thermal cycler and later processed for either mtDNA or msDNA analysis. MtDNA-RFLP marker analysis is a method where genomic DNA is cut with restriction enzymes and the products are separated by size through agarose gel electrophoresis. The presence or absence of multiple restriction sequences around a given DNA region represent haplotypes (Silva and Russo 2000). These haplotypes are scored from fragments that are visualized as bands on stained agarose gels. Genetic marker variability data are based on the scored haplotypes.

Meanwhile, microsatellite DNA are short stretches of DNA composed of tandemly repeated arrays of di-, tri- or tetranucleotides (Wright and Bentzen 1994). Changes in each microsatellite locus are usually noted as insertions or deletions during DNA replication or by recombination between DNA molecules (Goldstein and Scholterrer 1999). These allele length polymorphisms that result from changes in the number of repeats are quantified by sizing PCR-amplified copies of the DNA on a polyacrylamide gel (Stepien and Kocher 1997). MsDNA on the gel are blotted and hybridized onto nylon membranes. Genetic marker data based on msDNA variation is obtained from scoring banding patterns visible on nylon membranes that have been earlier stained through a chemoluminescent method. MsDNA markers exhibit high levels of genetic variability. These markers have the potential to isolate large numbers of gene loci and therefore provide a marker system that can detect differences even among closely related populations (O'Connell and Wright 1997).

Genetic markers – uses, advantages and limitations

In stock enhancement programs, genetic markers are extremely useful in marking stocks, studying the population structure of threatened or endangered species (Ward and Grewe 1994), measuring genetic differences and changes within and between released hatchery-bred stocks and wild populations, determining the fate of reared animals after deliberate or inadvertent release in the wild (Cross 2000), and identifying the presence of intraspecific hybrids (between wild and hatchery stocks) in the release habitat. They are also generally useful in studies on fish populations especially in delineating the relative roles of microevolutionary forces that shape population structures (Sweijd et al 2000).

Genetic markers are heritable, stable and are non-invasive hence they do not affect the growth, health and behavior of the organism. Unlike physical tags or markers that should be applied prior to the release of tagged individuals in the wild, genetic marker information can be obtained from the individual organism even after they have been released and recaptured. Genetic markers therefore provide a means of tracking stocked animals without necessarily handling them individually before release. How is this done? In stock enhancement, the parental stocks that are used to breed the released hatchery stocks are genetically documented using molecular markers. The hatchery-bred individuals are then released and allowed to grow in the natural habitat. After some time, samples from stocks in the natural habitat are collected and the individuals are genetically marked and their genotypes compared with the parental stocks to trace the pedigree of both the wild and released hatchery stocks. This method is referred to as parentage analysis or pedigree tracing.

Although use of genetic markers present several advantages, there are also limitations to the application of genetic markers. When the level of detectable genetic variation within and between stocks is small and negligible, genetic marker methods may not be suitable. Furthermore, genetic marker analysis is quite costly and requires technical expertise.

DNA marker analysis data

DNA sequence information can be determined from individual organisms using modern molecular genetic methods and equipment. Several parameters (e.g., allele frequency and levels of heterozygosity) that measure genetic variation can be inferred from DNA marker analysis. These indices of genetic variability can be measured at the individual, stock and species levels. The inbreeding coefficient within a particular stock or population and through subsequent generations can be inferred from DNA markers, particularly through microsatellite marker analysis. Based on data generated from genetic or DNA marker analysis, stock structure analysis is possible, genetic diversity can be conserved and other genetic concerns can be addressed if all these genetic variability indices are known.

Genetic Markers in Stock Enhancement

The success of any stock enhancement program lies heavily on the assumption that released hatchery-bred stocks can adapt well and survive in the natural environment. Genetic diversity is an important component of adaptation and evolutionary success. A change in the genetic structure of a particular organism or group of organisms is equivalent to a change in the fitness or the ability of the population to thrive in the release habitat. Loss of genetic diversity often occurs in small populations with few founder stocks (such as hatchery stocks). It is likely that the individuals in these populations are closely related to each other and when mated through generations, the probability of inbreeding becomes higher. Inbreeding causes inbreeding depression that may be expressed as poor fitness, apart from abnormalities and slow growth. Low genetic variability may thus result in poor adaptability or reduced fitness (Moritz 1994). Hence hatchery-bred stocks with low genetic diversity may not survive well in wild or natural habitats (Allendorf et al 1988). It is in this regard that genetic diversity should be conserved if only because genetic variability contributes directly to fitness-related traits. Genetic diversity or variability can be evaluated and monitored through genetic marker analysis. Hence this emphasizes the significant role of genetic markers in conservation and stock enhancement programs.

Genetic Concerns in Stock Enhancement

There are several genetics issues which must be fully understood and considered in any stock enhancement program. The evolution of genetic differences between wild and hatchery stocks is a concern. Hatchery-bred stocks genetically differ and sometimes fare poorly compared to wild stocks. Several studies have shown that some hatchery stocks suffer loss of genetic variation due to random genetic drift, domestication and inbreeding (Allendorf and Phelps 1980, Cross and King 1983, Doyle 1983, Ståhl 1983, Taniguchi et al 1983, Ferguson et al 1991).

Both domestication and inbreeding contribute to the continuous erosion of genetic variation within the hatchery stocks. How does this occur? The inbreeding coefficient is inversely proportional to effective population size or $F = 1/(2Ne)$ (Falconer 1981). The higher the effective population size, the possibility of inbreeding would be lower. In contrast to the actual population size (N)

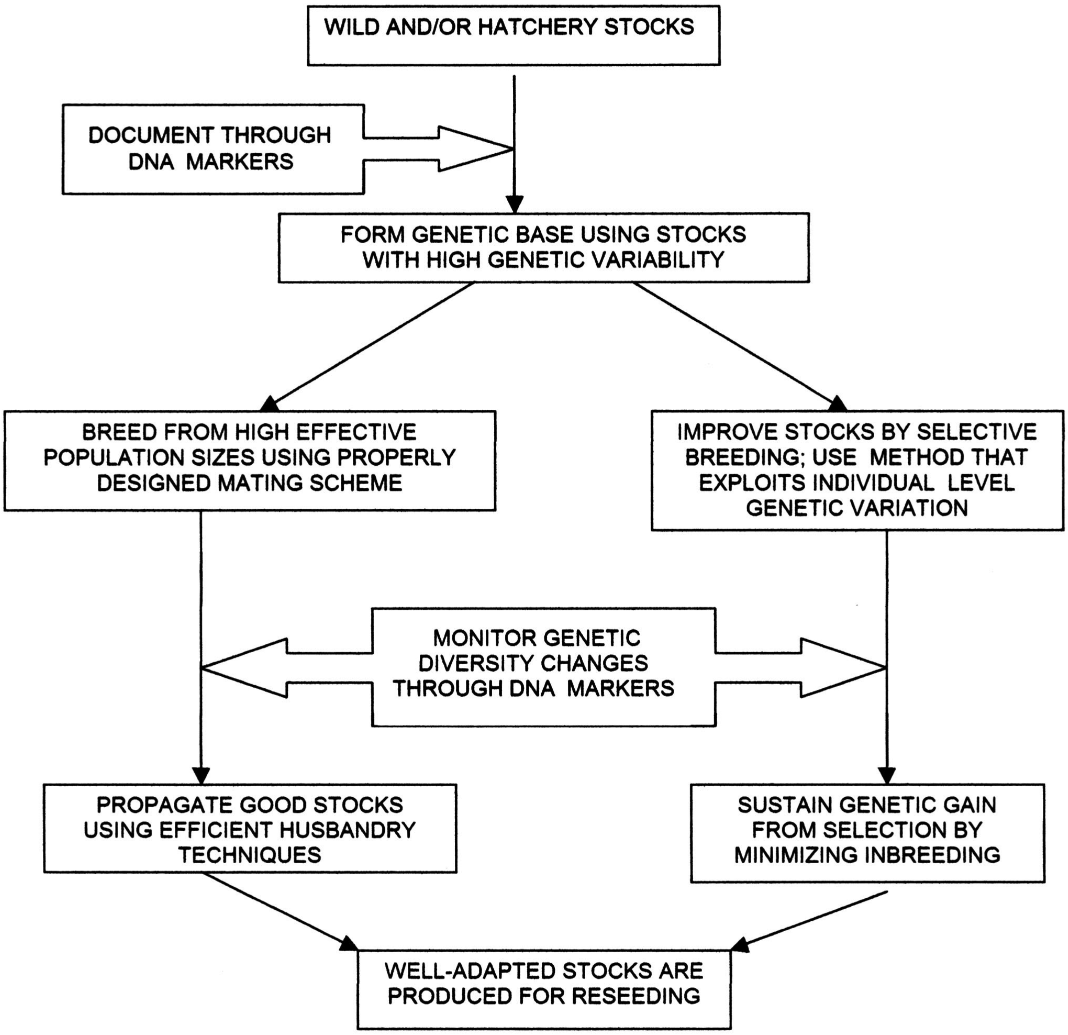

Fig. 1. Recommended scheme for the sustainable management of wild/hatchery stocks used for reseeding.

which is the number of male and female breeding individuals that are set up as broodstock to produce the next generation, effective population (Ne) is the total number of males and females that actually mate and contribute to the gene pool of subsequent generations. Fish breeding in the hatchery is normally based on few founder stocks. This alone already limits the number of effective females and males that mate and contribute to the next generation so the situation hastens the loss of genetic diversity in hatchery-bred stocks. The genes (and therefore the traits that are expressed) present in the hatchery stock that are most suitable to hatchery conditions will increase in frequency (Allendorf et al 1988). The individuals possessing the so-called "hatchery-adapted" traits will fail to survive or grow well in the natural habitat.

This issue can be addressed by either a) increasing the effective population size in the hatchery that produces the seedstock for release in the wild (Taniguchi 2003) or by b) collecting wild broodstock for breeding in the hatchery and releasing their young in the natural habitat. The second method is known as supportive breeding.

A third main concern is the genetic “contamination” of the wild stocks in the area where stock enhancement efforts are being implemented. It is believed that if hatchery-bred aquatic organisms have low genetic variability, when these stocks are released in the wild, introgression between the highly variable wild stock and the genetically depauperate hatchery stocks would inevitably occur because of interbreeding. When gene introgression happens, there is concern that the frequency of nondaptive “hatchery” genes might increase (Allendorf et al 1987). The occurrence of interbreeding can be checked by examining the genetic diversity and structure of stocks found in the release habitat through genetic markers.

Recommendations

Figure 1 shows the recommended scheme for the sustainable management of wild/ hatchery stocks used for re-seeding. In a stock enhancement program, both wild and hatchery stocks can be documented genetically through DNA markers. From this genetic database, stocks that have high genetic variability can be chosen and utilized as the founder stocks. If enough individuals can be used as founder stocks, a high effective population size would be desirable to use for breeding in the hatchery. Genetic changes are again monitored in the hatchery-bred offspring. The progeny are then reared onwards using efficient husbandry techniques. These purportedly well-adapted stocks can be used for reseeding purposes. On the other hand, if the size of the population is insufficient to provide a high Ne, the existing hatchery stocks can be further improved through selective breeding. These stocks are continuously monitored for genetic changes using DNA marker analysis. Monitoring genetic changes in stocks can help determine whether the aquaculture stocks can still be used in propagating seedstock for stock enhancement. If the aquaculture stocks can still be used, selective breeding can be done while simultaneously adopting mating schemes that can minimize inbreeding. Well-adapted stocks may be chosen from the progeny and reared onwards for use as seedstock in stock enhancement activities.

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The SEAFDEC/AQD Experience in Stock Enhancement

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Introduction

Populations of some aquatic animals such as sea turtles, humphead wrasse *(Cheilinus undulates)*, seahorses *(Hippocampus* spp.*)* sharks and rays, sea cucumbers (*Holothuria* spp.), giant clams (particularly the true giant clam *Tridacna gigas*) and abalone (*Haliotis* spp.) which provide livelihood for local fisherfolk have become highly depleted or threatened due to destruction of habitat and/or overexploitation. Therefore we must seek sustainable management of natural stocks of these species. Stock enhancement is a well known method of replenishing depleted stocks.

The Aquaculture Department (AQD) of the Southeast Asian Fisheries Development Center (SEAFDEC) started stock enhancement activities in 2000 as part of the Coastal Fishery Management Project in Malalison Is., Culasi, Antique, Philippines (SEAFDEC/AQD 1998). This was the same year as the Bangkok Declaration and Strategy for Aquaculture Development (NACA/FAO 2000), which affirmed the potential of stock enhancement to increase fish supply. Since then, research on seed production, and release and monitoring strategies has been initiated on the abalone *Haliotis asinina*, seahorses *Hippocampus barbouri* and *H. kuda*, mud crabs *Scylla serrata*, *S. olivacea* and *S. tranquebarica*, top shell *Trochus niloticus*, and window-pane oyster *Placuna placenta*. Closing the life cycle and mass production of juveniles have been attained for most of these species, but actual releases have been conducted only for abalone and mud crabs. In this review article, we describe the present situation of stock enhancement of abalone, mud crab and seahorse at AQD.

Abalone

Research and development of abalone at AQD started in 1994. Around 10,000-47,000 juveniles have been produced yearly since 1998. A diet-based bluish-green shell band was used to mark later batches, and exposure to predators and natural food provided behavioral conditioning. Packing and transport techniques have been refined using polyethylene vinyl chloride (PVC) pipes in styrofoam boxes. Releases in 2002-2004 in the Sagay Marine Reserve (SMR), Negros Occidental show recapture rates of 4.2% after one mo, and up to 6.9% after 6 mo (Gallardo et al unpub. manuscript).

Stock assessment and marking of release site

Existing abalone stocks in the release site were assessed by counting abalones found along a 1-m band on both sides of a 25-m transect line (belt-transect method) and measuring their sizes. Species composition and abundance of seaweeds, crabs, mollusks and fishes particularly carnivorous species were determined using transects and quadrats (Gallardo et al unpub. manuscript). This assessment revealed that the intertidal Carbin Reef in SMR is a natural abalone habitat suitable for release; it is exposed during the lowest tides. Points for deployment of release modules were marked using PVC plates and numbered PVC pipes along a 25-m nylon rope.

Seed production

Juvenile abalone of 10-12 mm shell length (SL) were fed a SEAFDEC/AQD–formulated diet for 2-3 weeks to produce a small bluish-green shell band which served as permanent marker (Gallardo et al 2003). They were subsequently fed the brown seaweed *Gracilariopsis bailinae* to produce the natural brownish shell after formation of a bluish-green band 6 mm wide. The colored band served as natural marker.

Three to four days before release, abalones were trained to forage for food among naturally growing seaweeds or an added supply of the seaweed *G. bailinae*, and to escape predators by stocking them with the crab *Metopograpsus latifrons*, fish *Epinephelus coioides*, and gastropod *Pleuroploca trapezium*, and with shelters (Schiel and Welden 1987, Brown and Day 2002, Buen 2005) either in flow-through outdoor tanks or in indoor tanks.

Packing and transport

Prior to transport, juveniles were tagged individually with numbered, color-coded (by size group) Dymo tape glued to the shell for monitoring. Shell length, body weight and gonadal stage were recorded. Samples of the epipodia of foot muscle were taken from each released abalone and preserved for DNA analysis to determine if future juveniles in the release sites are their offspring. After tagging and sampling, 20 abalones per size group were placed in the numbered release modules stocked in flow-through tanks. The modules were made of 5.1 or 7.6 cm diameter x 15.2 cm long PVC pipes covered on both ends with mesh net. The PVC pipes containing abalones were placed inside double-layered plastic bags without seawater but provided with oxygen and placed in styrofoam boxes with small packs of seawater ice to maintain low inside temperature. Abalone survival within 8 h of transport was 100% as in the June 2002, October 2002 and March 2004 batches. When transport time exceeded 8 h, mortalities occurred, e.g., the April 2003 batch had 3.5% mortality after 9 h, maybe due to oxygen depletion and temperature increase (Gallardo et al unpub. manuscript).

Release and monitoring

In June 2002, a total of 1,800 diet-tagged abalones of four sizes (SL 1.5, 2.5, 3.5-4 and 4.5-5 cm), at 450 abalones per size group were released in the SMR Carbin Reef during neap tide. Upon arrival, the PVC pipes were sprinkled with seawater from the release site to acclimate the abalones. For protection from predators, the pipes containing all abalone sizes were placed inside net bags with bottom holes to allow exit of abalones (McCormick et al 1994). Each release module (comprising 5 pipes per net bag) was tied to the corresponding number of PVC pipe along the nylon rope within the plot. The nets covering both ends of the pipe were removed to release the abalones. The net bags containing pipes prevented predators from directly entering the pipes thereby protecting the abalones. Monitoring was carried out immediately after module deployment and twice daily for 3 days after release. The distance from release point to where the abalones were sighted was measured using a tape; dead abalones and empty shells were collected and recorded. Based on higher survival of medium-sized abalones in the June 2002 release, 3-cm SL juveniles were used for releases in October 2002, April 2003 and March 2004 in different sites of Carbin Reef with 2,500 pieces per release.

Exit from release modules, dispersal and survival after release

The released abalones were monitored from the release point without destroying or turning over corals and rocks. In June 2002, the abalones left the release modules within the first 2 h. Only 2.3% remained in the modules by the third day. Dispersal from the release point was within 1 m, except for some large abalones found 4 m from the

Table 1. Dispersal distance (means and ranges) of abalone *Haliotis asinina* released in Carbin Reef, Sagay Marine Reserve, Negros Occ., Philippines in June 2002.

Size group (shell length)	**Distance from release point (cm)**		
	Day 1	Day 2	Day 3
Small (2.5-3.0 cm)	63.7 (23-143)	29.7 (16-51)	54.6 (16-120)
Medium (3.5-4.0 cm)	61.2 (5-400)	64.0 (5-400)	92.7 (10-234)
Large (4.5-5.0 cm)	72.6 (25-400)	40.0 (21-100)	131.9 (8-400)

release point (Table 1). In the October 2002 batch, almost all of the abalones left the modules by day 3 but remained within 1 m from the release point. In the April 2003 and March 2004 batches, small abalones left earlier but did not disperse as widely as the medium and large ones (Table 2).

In the June 2002 batch, 27 pieces of whole and broken shells (1.5% of total released [27/1800=0.015]) were found (Table 3). Whole shells probably came from abalones that died from handling stress and/or predation by carnivorous fishes and gastropods, whereas broken shells were due to reef crabs which prey on abalone (Tegner and Butler 1985). Crab predation can be recognized by the chipped margin of abalone shells (Shepherd and Breen 1992). After one month, a total of 52 empty shells were found of which 53.8% were large (4.5-5.0 cm SL), perhaps because the bigger ones have greater exposure to predators being more visible with a tendency to move farther away. The smaller abalones have higher survival because they are more cryptic and do not move far from the release point. This is confirmed by results of the October 2002

Table 2. Dispersal distance (means and ranges) of abalone *Haliotis asinina* released in Carbin Reef, Sagay Marine Reserve, Negros Occ., Philippines in April 2003 and March 2004.

Size group (shell length)	**Distance from release point (cm)**							
	April 2003*				March 2004*			
	Mean (±SD)	Range	N	%	Mean (±S.D)	Range	N	%
Very small (1.5-2.0 cm)	23.6 (4.6)	20-35	11	12.94				
Small (2.5-3.0 cm)	42.8 (38.1)	0-13.5	18	21.18	29.9 (18.2)	10-55	8	18.18
Medium (3.5-4.0 cm)	92.0 (76.6)	5-300	36	42.35	83.6 (131.5)	0-500	12	27.27
Large (4.5-5.0 cm)	137.4 (105.1)	5-383	20	23.53	145.6 (159.0)	0-770	24	54.54
Total			85				44	

*2,500 abalones per release

Table 3. Post-release mortalities of abalone *Haliotis asinina* in Carbin Reef, Sagay Marine Reserve, Negros Occ., Philippines in June 2002, April 2003 and March 2004.

Size group (shell length)	**June 2002***				**April 2003****	**March 2004***			
	Day			Total	Day	Day			Total
	1	2	3		3	1	2	3	
Extra small (1.5-2.0 cm)									
Whole shell					1				
Broken shell					0				
Small (2.5-3.0 cm)									
Whole shell	1	1	2	4	0	0	0	0	0
Broken shell	1	0	0	1	1	0	6	1	7
Medium (3.5-4.0 cm)									
Whole shell	2	2	2	6	6	0	0	2	2
Broken shell	2	0	1	3	0	0	1	5	6
Large (4.5-5.0 cm)									
Whole shell	2	2	4	8	14	0	0	5	5
Broken shell	3	0	2	5	0	0	2	2	4
Total	11	5	11	27	22	0	9	15	24

*Monitoring from Day 1 to Day 3
**Monitoring on Day 3 only

release using 3-cm SL juveniles and the April 2003 and March 2004 (Table 3) releases using different sizes.

Recapture rates

One month after release of the June 2002 batch, 77 juveniles (38 large, 25 medium, and 14 small) or 4.2% of total releases were seen within 5 m from the release point. The total number could be higher with more intensive search, i.e., by turning over corals and rocks. Subsequent monitoring of the June 2002 and October 2002 releases was limited to 5 m from each side of the release point to avoid destroying corals in the marine reserve. Recapture rates were 12.3% and 6.9% after 2 and 6 mo, respectively. These figures are lower than the reported 16-21% recapture rate after 6 mo for *Haliotis midae* in South Africa (Sweijd et al 1998) but higher than the <1% recapture rate after 6 mo for *H. rufescens* in Northern California (Rogers-Bennett and Pearse 1998). For the temperate *H. discus hannai* in Japan, the recapture rate is 5-10% after 2-3 yr upon reaching marketable size (Masuda and Tsukamoto 1998).

Mud Crabs

Mud crabs of the genus *Scylla* are highly prized as food, and therefore subject to heavy fishing pressure all over Asia and Australia. One of the three principal strategies to replenish

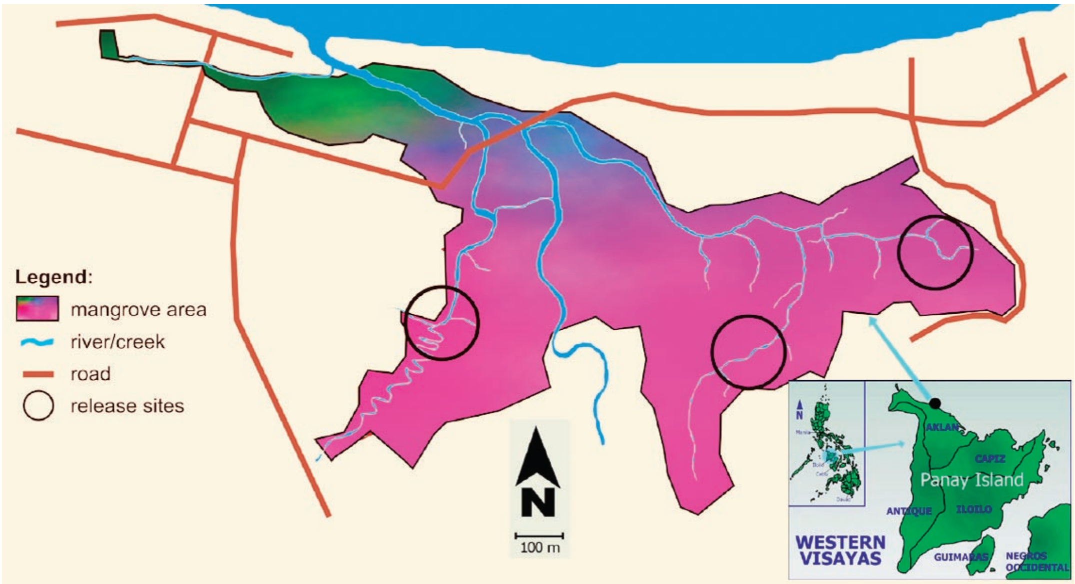

Fig. 1. Release sites of tagged crabs for stock enhancement trials in the mangroves of Naisud and Bugtong Bato, Ibajay, Aklan, central Philippines.

depleted stocks and manage fishery yield is to increase recruitment through propagation and release, that is, through stock enhancement (Blankenship and Leber 1995), hence this study was conducted.

Seed production

Zoeae were reared in 1-ton and 10-ton tanks at 60-80/L and fed rotifers and *Artemia* (Quinitio and Parado-Estepa 2003). Water exchange was 30-50% depending on the water quality. Megalopae were produced in 15-18 days and crab instar (C) in 21-23 days after hatching. Megalopae or crab instar were further grown to ≥2 cm carapace width (CW) in 10-ton concrete tanks or in net cages installed in earthen brackishwater ponds. Crabs were fed fish and mollusks. The crabs were then released directly in ponds for another 3-4 weeks or until they reached the desired size of 3-6 cm CW for stock enhancement.

Tagging and transport

One day before release, crabs were tagged with a coded microwire tag at the base of the left third walking leg or pereopod. Released crabs measured 30.0-79.9 mm CW, excluding mature females. They were transported in native palm bags to the release site; travel time was approximately one hour. First release was on 4 May 2004. Monitoring of tagged crabs started during the 18-21 June 2004 spring tide and every spring tide thereafter.

Hatchery–produced *S. serrata* and *S. tranquebarica* were obtained from the Crustacean Hatchery of SEAFDEC/AQD. Crabs were reared individually in perforated plastic containers altogether placed in concrete tanks provided with filtered seawater. Juvenile crabs were tagged for release at a minimum size of 30 mm CW. Crabs were measured, sorted and grouped into size classes from 30.0 to 79.9 mm CW at 4.9 mm intervals and placed in containers; mature females were excluded. Each crab was injected at the base of the third walking leg on the left side. Tagging was done in the hatchery a day before release. Tagged crabs were placed in containers and transported the following day to the release site, approximately 210 km from the hatchery.

Table 4. Mud crabs *Scylla olivacea, S. serrata* and *S. tranquebarica* caught in Ibajay, Akan, central Philippines in June 2004–April 2005.

Month	No. crabs caught	% crabs tagged (cumulative rate)
Jun 2004	651	11.52
Jul 2004	505	25.74
Aug 2004	364	27.47
Sep 2004	179	34.64
Oct 2004	252	21.83
Nov 2004	332	33.73
Dec 2004	403	38.96
Jan 2005	402	33.58
Feb 2005	599	32.89
Mar 2005	576	47.92
Apr 2005	427	59.25

Stock enhancement

Stock enhancement trials were conducted in a natural mangrove stand in the villages of Bugtong Bato and Naisud in Ibajay, Aklan province, Philippines. The study site is home to 27 of the 34 species of mangroves found in the Philippines (Agbayani et al 2000, Primavera et al 2004). Three release sites located at the end of each of the major branches of the Naisud river system were chosen for this activity (Fig. 1). Release of crabs was done during the spring tide of each month from May 2004 to April 2005, except in October 2004. Three species of crabs were released – *S. olivacea* from the replanted mangroves of New Buswang, Kalibo Aklan; and *S. serrata* and *S. tranquebarica* from the Crustacean Hatchery of SEAFDEC/AQD.

A total of 5,161 *Scylla* spp. have been released, comprising 34.66% wild *S. olivacea*, 58.86% hatchery-reared *S. serrata*, and 6.47% hatchery-reared *S. tranquebarica*. Of the 3,040 *S. serrata*, 60% were released straight from the hatchery while 40% were conditioned for at least one month prior to stocking in nursery ponds of the Dumangas Brackishwater Station of SEAFDEC/AQD. Conditioning was done by stocking crabs in ponds allowing exposure to scavenging, competition, predation and variations in environmental conditions.

Scylla spp. landings showed increasing retrieval of tagged crabs from 11.5% in June 2004 to 59.3 in April 2005 (Table 4). From June 2004 to April 2005, one third of total catches were tagged crabs (1,552 of 4,690 total) of which 52.1% were *S. olivacea*, 40.7% *S. serrata* and 7.2% *S. tranquebarica* (Table 5). Recapture rate of tagged crabs was highest for

Table 5. Mud crabs *Scylla* spp. released and recaptured in Ibajay, Aklan, central Philippines.

Species/source	No. of crabs tagged, released (% of total)	No. (%) of tagged crabs recaptured	Recapture rate (%)
Scylla olivacea/Wild	1,789 (34.66)	809 (52.12)	45.22
Scylla serrata/Hatchery	3,038 (58.86)	631 (40.66)	20.77
Scylla tranquebarica/Hatchery	334 (6.47)	112 (7.22)	33.53
Total	5,161 (100.00)	1,552 (100.00)	

Tags have been read but not yet analyzed as to batch released.

S. olivacea (45.2%), followed by *S. tranquebarica* (33.5%) and lowest for *S. serrata* (20.8%). Preconditioned *S. serrata* had higher recapture rates (mean=37.1%) compared to non-conditioned crabs (mean=10.2%). Conditioning hatchery-reared crabs has been shown to improve survival in the wild. Hatchery-reared, conditioned crabs had higher recovery and growth rates compared to hatchery-reared, non-conditioned ones, and even comparable to wild-released crabs in the case of *S. olivacea*. Crabs conditioned in the pond had been exposed to competition, cannibalism, temperature and salinity fluctuations, and had experienced foraging for food. There is evidence that performance and survival of hatchery-reared animals can be improved to the same level as their wild counterparts by conditioning steps in the hatchery prior to release in natural habitats (Davis et al 2005). Conditioning has likewise proven to be effective in increasing fitness of hatchery-reared *Homarus gammarus* (Wickens 1986, van der Meeren 2001) and *Callinectes sapidus* (Davis et al 2005). The results of this study show the importance of conditioning in improving success and efficiency of stock enhancement by compensating for deficiencies in hatchery-reared organisms.

Growth was also compared between species and between sources of juveniles to identify suitable species for a given area and suitable source of stock for future resource management and stock enhancement programs. Regardless of source, *S. olivacea* showed the fastest growth rate and *S. serrata* the slowest; *S. tranquebarica* had an intermediate rate. The observed growth rates of wild-released *S. olivacea* are comparable to those for the same species cultured in ponds (0.12-0.25 mm/d) (Fortes 1999). However, growth rates obtained for all species regardless of source were lower compared to the growth rates obtained by Triño et al (1999) for pond culture of mixed *S. serrata* and *S. tranquebarica* (1.1 mm/d) and Walton et al (2006) for wild *S. paramamosain* (0.67 mm/d).

Seahorses

Fisheries

Seahorses are one of the most heavily exploited groups in the Philippines. The seahorse fishery (primarily *Hippocampus comes*) in northwestern Bohol has declined to 70% since 1985 (A. Vincent, unpub. data as cited by Perante et al 2002, Vincent and Koldeway, this volume). Other existing seahorse fishery grounds in Palawan, Panay and parts of Mindanao remain unassessed.

Seahorses are caught using small nets or collected as by-catch in trawls and seine nets. They are traded in dried form for traditional Chinese medicine, tonic food and curiosities; and as live animals for the ornamental fish industry (Lourie et al 1999). Seahorses are exported to North America, Europe and Japan (Vincent 1996). Due to increased fishing effort, fishers claim that seahorse catches have declined significantly since 1985 (Vincent 1996). Many species of seahorses are listed as Vulnerable in the 2000 Red List of Threatened Species of the World Conservation Union (Hilton-Taylor 2000), and all species of genus *Hippocampus* are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 2002.

Resource management

Established in 1996, Project Seahorse is an integrated program of conservation and management initiatives. It includes community-based conservation in fishing villages, e.g., establishment of no-take marine sanctuaries, fisheries modification and management, enforcement of legislation, education programs and development of alternative livelihoods for seahorse fishers (Lourie et al 1999).

Breeding and seed production

The SEAFDEC/AQD initiated seahorse breeding and seed production studies in 1995. By 2000, the F_3 and F_2 generation had been attained for *H. barbouri* and *H. kuda*, respectively.

Mating pairs of *H. kuda* continually reproduced throughout the year, but parturition frequency appeared to peak during February to April when seawater temperature and photoperiod started to increase, and decreased during low seawater temperature and short photoperiod in November to January. *H. kuda* produced broods of up to 1,751 juveniles and a parturition interval of 12 d (Hilomen-Garcia and Garcia 2004). Survival rate of a brood could reach 99% in 10 days, demonstrating a high potential for seed production. Mating pairs of *H. kuda* and *H. barbouri* offered either DHA Selco-enriched *Artemia* adults, mysids, or their combination had comparable frequency of parturition and produced similar brood size and stretched height of newly born juveniles. Likewise, survival rates on day 10 were comparable (SEAFDEC/AQD 2000).

Newly-born *H. kuda* offered a variety of food organisms preferred copepods (mostly *Pseudodiaptomus annandalei* and *Acartia tsuensis*) to rotifers (*Brachionus rotundiformis*)(Celino 2000). Size and amount of food ingested increased as seahorses grew. Increase in body weight was highest (5% per day) and mortality rate lowest (9% on day 10) in seahorses fed a combination of copepods and rotifers. Seahorses fed rotifers alone had the slowest growth rate (0.3% per day) and highest mortality rate (60% on day 7). The results indicate that copepods are suitable food organisms for seahorse juveniles but availability of a diversity of food organisms in the tank improves survival and growth of *H. kuda* in captivity.

Nine week-old hatchery-reared *H. kuda* transferred from ambient seawater (32-33 ppt) to salinities ranging from freshwater to 85 ppt were able to survive at 15 ppt for at least 18 days without affecting growth and survival (Hilomen-Garcia et al 2003). Mortality occurred within 4-24 h in seahorses abruptly transferred to freshwater, while survival of 5 ppt-reared seahorses decreased to about 65% in 18 days; and the upper limit of salinity tolerance was 50 ppt. The best stocking density for newly born *H. kuda* in tanks was noted to be ≥5 seahorse/L and one seahorse/L on day 20 (SEAFDEC/AQD 1999).

Nursery and grow-out

To continue the existing hatchery protocols for mass production of *H. kuda* for trade and possible stock enhancement, *H. kuda* juveniles were reared in illuminated marine cages (Garcia and Hilomen-Garcia unpub. manuscript). One group each of juvenile seahorses was fed *Acetes* in lighted and unlighted marine cages while a third group in lighted cages was not fed. After 10-12 weeks, mean body weight and stretch height increased in all treatment groups, with juveniles fed *Acetes* in lighted cages showing greater sizes than the two other treatment groups. The results indicate that *H. kuda* juveniles may be grown in lighted cages with *Acetes* to supplement the natural diet of zooplankton (attracted by light).

Conclusions

The basic technology for seed production of abalone, mud crab and seahorse is already established at AQD. However, some techniques need further development. Survival rates of juveniles are low due to cannibalism and lack of suitable feeds for mud crab and seahorse, respectively. In addition, more intensive studies on release strategies such as tagging and monitoring are needed. Social preparation of local communities that are the actual managers in the release sites is also required. To solve these problems, the SEAFDEC/AQD is implementing the project on Stock Enhancement of Threatened Species funded by the Government of Japan.

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Biology and Status of Aquaculture for Giant Clams (Tridacnidae) in the Ryukyu Islands, Southern Japan

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Introduction

The Ryukyu Islands consist of many islands located between Kyushu in mainland Japan and Taiwan. The islands in the southwestern area of the Ryukyu Islands belong to the Okinawa Prefecture (Fig. 1). The Ryukyu Islands are strongly affected by the Kuroshio Current and are renowned for their coral reefs with high diversity of tropical and subtropical species.

Giant clams traditionally have been utilized as fisheries resources for a long time in this area. According to fisheries statistics, catches of *Tridacna crocea* in Okinawa have decreased drastically during the last 30 years and currently are less than one tenth of previous catches (Fig. 2). Fishing can easily deplete stocks of giant clams because the clams inhabit shallow waters and take at least three years to attain sexual maturity.

Techniques for the mass seed production and aquaculture of three species (*T. crocea, T. squamosa,* and *T. derasa*) were established in Okinawa. Four hundred thousand seeds of giant clams of 8 mm shell length (SL) are supplied to fishermen for use in aquaculture or stock enhancement every year.

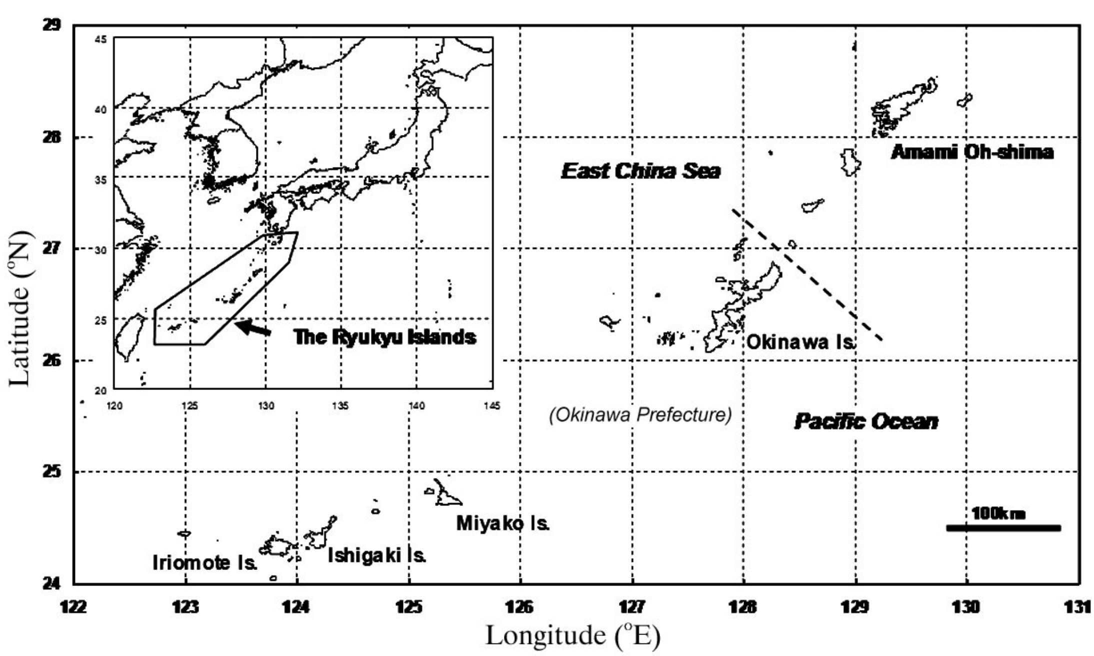


Fig. 1. Map showing location of the Ryukyu Islands in southern Japan.

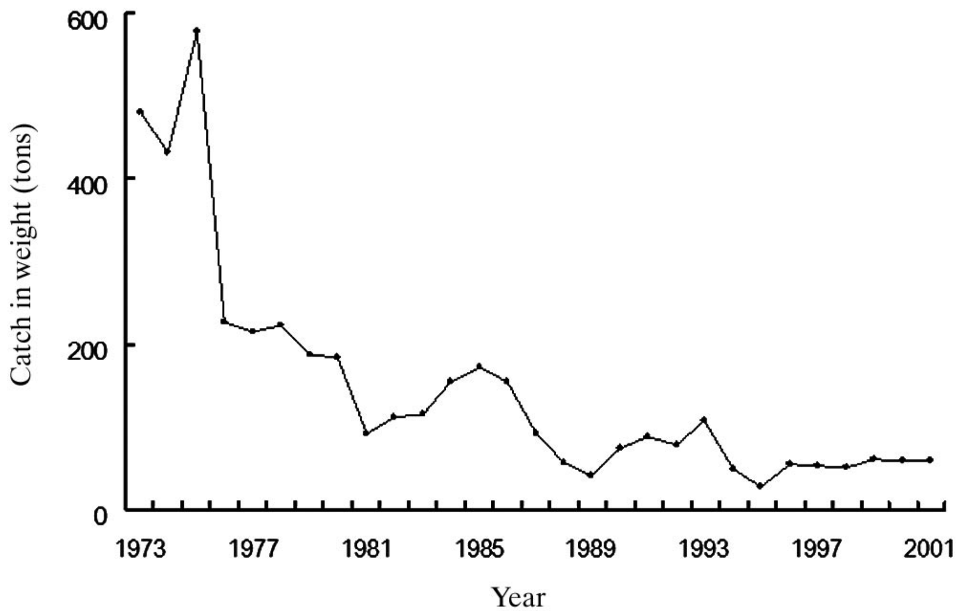


Fig. 2. Annual catches (tons) of *Tridacna crocea* in Okinawa, Japan.

This paper will review the (1) biology of giant clams, (2) present status of aquaculture of giant clams in Okinawa, and (3) other studies on giant clams in southern Japan.

Biology of Giant Clams

Classification of giant clams

Classification of giant clams is shown as follows:

Phylum: Mollusca
Class: Bivalvia
Order: Veneroidea
Superfamily: Cardioidea
Family: Tridacnidae (Giant clams)
Genera: *Tridacna* and *Hippopus*

Giant clams are distributed on coral reefs and areas adjacent to reefs in the Western Pacific and Indian Ocean. Nine species of giant clams belonging to two genera in the family Tridacnidae are currently known to science (Knop 1996). Three species (*T. tevoroa, T. rosewateri,* and *Hippopus porcellanus*) have been discovered in the 1980s and 1990s, but the areas where they are distributed are limited.

Giant clam species in the Ryukyu Islands and morphological characters

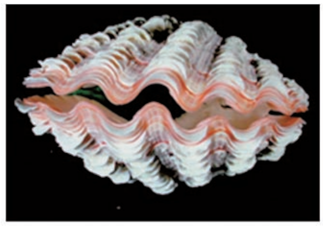
In the Ryukyu Islands, six species of giant clams have been recorded including five extant species, *T. crocea*, *T. squamosa*, *T. derasa*, *T. maxima*, *H. hippopus* (Fig. 3) and *T. gigas,* although the latter species has rarely been found in this area recently.

Murakoshi (1988) described the morphological characters of the five extant species as follows:

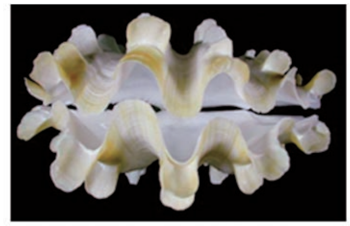
T. crocea is the smallest of the five species and grows to 15 cm SL. There are short scutes on the radial ribs and unequal anterior and posterior sides of the shell margin. This species shows marked variations in mantle colors. It has the best taste among the five species and it is the most important species of giant clam as a fisheries resource in the Ryukyu area.

T. squamosa reaches about 40 cm SL. The anterior and posterior sides of the

Tridacna derasa

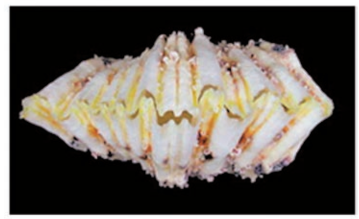


Tridacna crocea



Tridacna squamosa

Tridacna maxima



Hippopus hippopus

Fig. 3. The extant species of giant clams in the Ryukyu Islands, Japan.

lower shell margin are almost equal and large regular scutes exist on the radial ribs.

T. derasa is the largest of the five species and grows to 50-60 cm SL. The anterior and posterior parts of the lower shell margin are unequal. There are no scutes and the shell surface is smooth. The byssus disappears as the clam grows to a large size.

T. maxima reaches 30-35 cm SL. Shell morphology of this species is similar to *T. crocea*. However, it is possible to distinguish between the two species by the size of the adductor muscle impression.

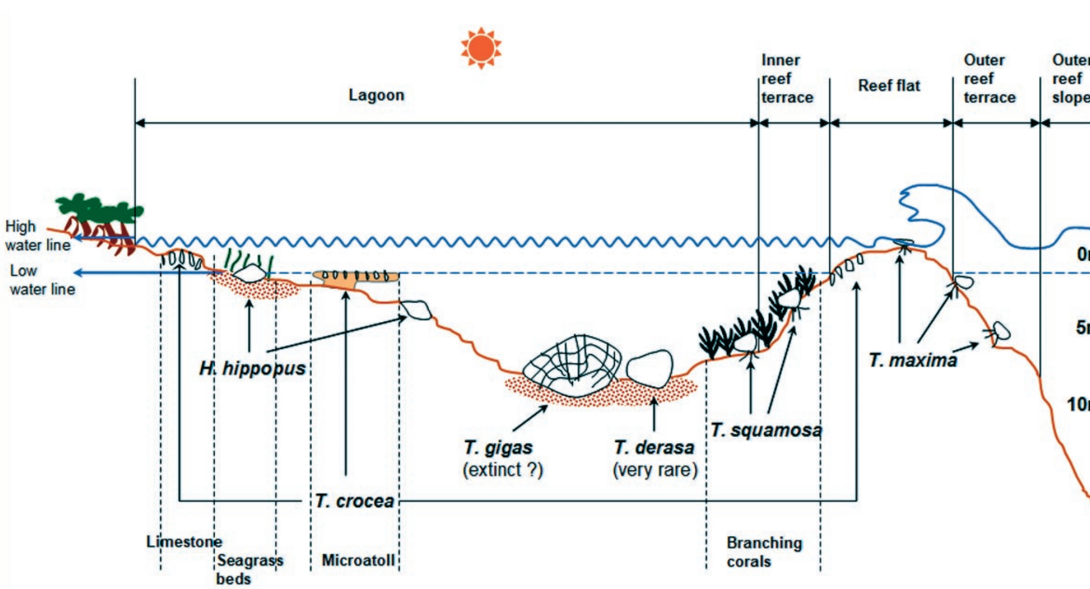


Fig. 4. Schematic illustration of major habitats of giant clams (*Tridacna crocea*, *T. squamosa*, *T. derasa*, *T. maxima*, *Hippopus hippopus*) in the Ryukyu Islands, Japan.

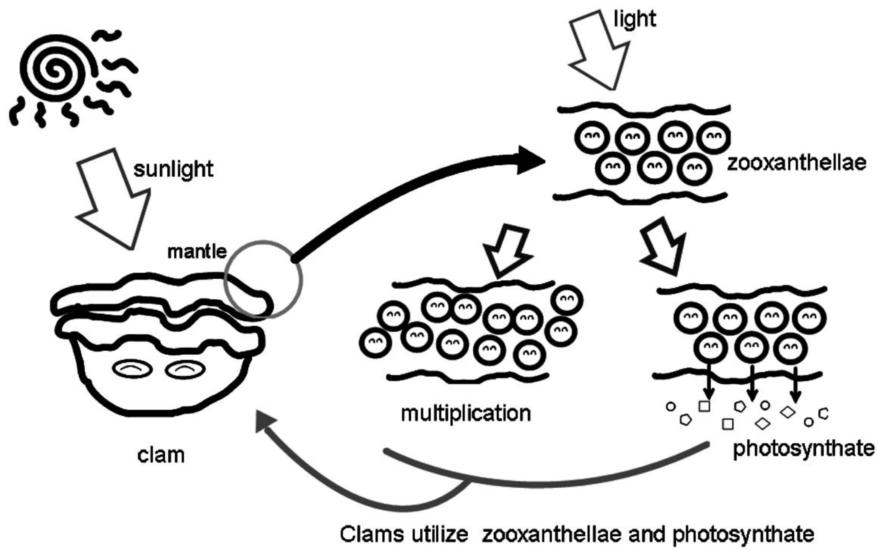


Fig. 5. Schematic illustration of the relationship between giant clams and zooxanthellae.

H. hippopus grows to 30-40 cm SL. The valves are diamond-shaped in adults and are quite different from those of other species. Their byssus orifices are nearly closed.

Habitats of giant clams in the Ryukyu Islands

Habitats of giant clams in the Ryukyu Islands are illustrated in Fig. 4. *T. crocea* bore into limestone substrates near the shore, on reef flats or dead parts of massive coral colonies, and most of the valves are hidden in the hollows. *T. squamosa* are found among branches of coral colonies in lagoons. *T. derasa* inhabit lagoons but this species is very rare in the Ryukyu Islands as this area is the northern limit of its distribution. *T. maxima* bury part of their shells in substrates at the outer reef edges where waves are rough and currents are strong. *H. hippopus* are generally found on sand or algal beds in lagoons.

Biological characteristics

Giant clams show the following biological characteristics during their life cycle.

The most distinctive character of giant clams compared with other mollusks is the symbiotic relationship with zooxanthellae. Zooxanthellae (*Symbiodinium* spp., Dinophyta) are 7-10 μm in diameter. The clam utilizes the photosynthetic products formed by the algae and consumes any excess algae in the mantle tissue directly (Fig. 5). Because the symbiotic alga is not transmitted through their eggs, the symbiotic relationship is established during larval development. Giant clams die if the symbiotic relationship with the zooxanthellae is not established.

Metamorphism occurs in the young stage so the symbiotic algae can obtain sunlight efficiently (Knop 1996). The larvae of giant clams do not differ markedly from other bivalves before metamorphosis. The shells are connected on their upper side by a ligament. The respiratory siphons stick out from one side of the shell. The gills are located in the central part of the larva. The larvae have two adductor muscles – anterior and posterior. After metamorphosis, the ligamentous joints move to the lower side and thus open upwards. The two siphons become separate and increase in length. The gills move to the upper side. The posterior adductor muscle moves to the center and the other one shrinks.

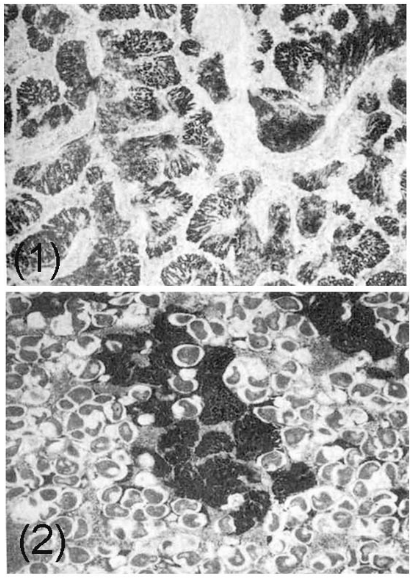


Fig. 6. Photomicrographs of histological sections of gonads in *T. crocea* (adapted from Murakoshi 1988): 1) Male-phase, 5 cm SL - testes are observed; 2) Hermaphrodite condition, 8 cm SL - ova and testes are observed.

Giant clams are protandric hermaphrodites (Wada 1952). *T. crocea* up to 5 cm SL are all males with testes. In clams over 5.5 cm SL, the testes are filled with sperm and ovaries are scattered among them (Fig. 6), the latter develop as the clams grow. *T. squamosa* up to 15 cm SL are all males with testes, while ovaries are found in shells over 17 cm SL (Leonid 1991).

Life cycle

The life cycle of giant clams is reported by Murakoshi (1988), Lucas (1988), Knop (1996), and Heslinga et al (1990).

As reported by Murakoshi (1988), the life cycle of *T. crocea* is shown in Fig. 7. Twenty hours after fertilization, eggs of *T. crocea* develop to D-shaped larvae of 0.14 mm SL. After a week of planktonic life, the larvae become pediveligers (0.19 mm SL) with both velum and foot, and gradually become benthic. After one more week, the velum gradually degenerates and the pediveligers develop into larval clams of 0.20-0.24 mm SL which begin to acquire symbiotic algae. The zooxanthellae which are ingested from seawater by the pediveligers move out through the wall of the gut, and the algae multiply. A row of algae reaching the ventral margin can be recognized as the establishment of symbiosis between larval clam and algae (Fig. 8).

Larval clams (0.25-0.50 mm SL) have conspicuous umbones and clear growth

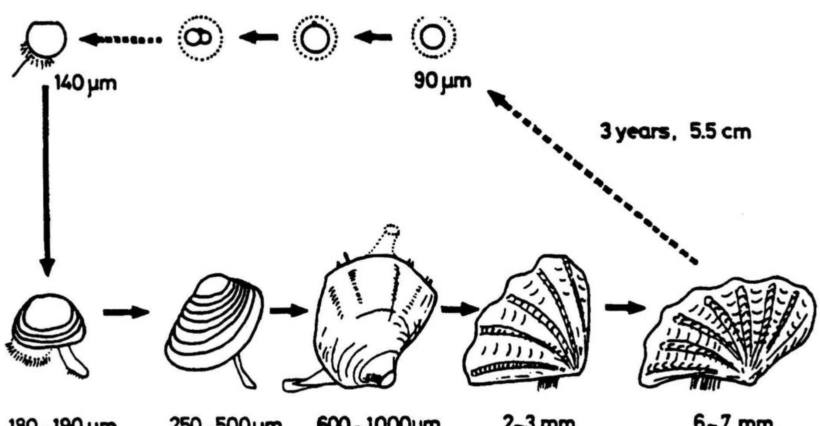


Fig. 7. Schematic illustration of the life cycle of *Tridacna crocea* (from Murakoshi 1988).

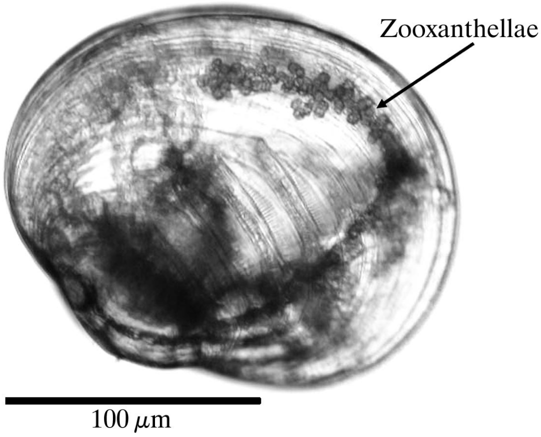


Fig. 8. Photomicrograph of larval clam of *Tridacna crocea* (0.2 mm SL) when the symbiotic relationship is first established.

lines on the shell. As the hinge area of the shell becomes large at 0.60-1.00 mm SL, remarkably long siphons develop. The radial ribs develop strongly and scutes appear on the shells as they grow thicker and become opaque. The mantle lobe is extended and the orifice of the byssus opens. The juvenile clams attach to substrates more firmly by the byssus. The shape of valves gradually changes from almost triangular at 2-3 mm SL juveniles to the adult shape in 6-7 mm SL juveniles. In about 3 years, they grow to 5.5 cm SL and start to reproduce.

Status of Giant Clam Aquaculture in Okinawa

Induction of spawning and egg collection

The water temperature around Ishigaki Island shows seasonal variation ranging from 20 to 30°C (Fig. 9). Mature clams appear from March to August and are brought from the sea to laboratory tanks where spawning is induced by artificial stimuli. One of the most effective methods is pouring gonad tissue dilution into the tank. Rapid changes of sunlight intensity are also used to stimulate spawning in *T. squamosa* and *T. derasa*. A light shielding net is used to cover the tank until spawning induction is performed on a sunny day.

In Okinawa, the spawning season falls in March-August for *T. squamosa*, March–May for *T. derasa*, and April-September for *T. crocea*. It is possible to check gonad development in *T. crocea* through the byssus orifice on the underside of the shell in order to select mature individuals.

Spawning usually releases sperm first, followed by eggs. The eggs are very small, about 90 μm in diameter. The range in number of spawned eggs is 5-20 million for *T. crocea*, and 10-100 million for *T. squamosa* and *T. derasa*. When the clams begin to spawn, they are immediately moved to another tank (500-l polycarbonate container) to avoid the effects of polyspermy. Spawning continues intermittently for 20-40 min. About 300 ml water with sperm is poured into the tank to fertilize the eggs. Fertilized eggs are stocked in the tank at a density of 6 eggs/ml. Strong aeration is necessary so the eggs do not settle on the tank bottom.

Seed production

Seed production procedures are outlined in Fig. 9. The day after fertilization, D-shaped larvae are transferred to another tank at a density of 0.3 larvae/ml. The indoor tanks are 10 tons (2 × 5 × 1 m) and 5 tons (1.2 × 4.0 × 1.0 m) in capacity. Moderate aeration is maintained to ensure water circulation in the tank (Fig. 10). It is necessary to provide zooxanthellae for the larvae, because the algae are not incorporated in the eggs of giant clams. Some of the ingested algae are digested in the gut of larval clams. The algae are provided to the larvae from Day-3 (3 days after hatching) at a density of 30-100 cells/ml.

There are two methods of obtaining zooxanthellae for use in larval culture. One

	Egg Larvae	(Establishment of symbiosis)		Juvenile		Seed (utility size)
Shell length	0.08mm	0.2mm	0.6~0.8mm	1mm	3mm	8mm
Day	Day 0	Day 10~30	Day 40~60	Day 60~80	Day 100~200	Day 150~300
Density	300,000/m^3	25,000/m^2	15,000/m^2	10,000/m^2	4,000/m^2	2,000/m^2
(Maximum)	(~500,000)	(~50,000)	(~30,000)	(~20,000)	(~6,000)	(~4,000)
Light intensity	~500 μ mol/m^2		~1000 μ mol/m^2	No light shielding		
Culture water	No running water	running water (1~2 times per day)	running water (ca. 1 times per h	running water (2~3 times per h)		
Exchange of water	one half 2 to 3 days	complete 10 to 20 days		complete 3 to 4 weeks		
Aeration	moderate / weak	No aeration				
Feed zooxanthellae	Fed (Day 3~)	Not fed				
Co-rearing with herbivorous gastropods				*Batillaria* spp.	*Trochus niloticus*	

Fig. 9. Procedure for seed production of giant clams at Yaeyama Branch, Okinawa Prefectural Fisheries Experimental Station, Japan.

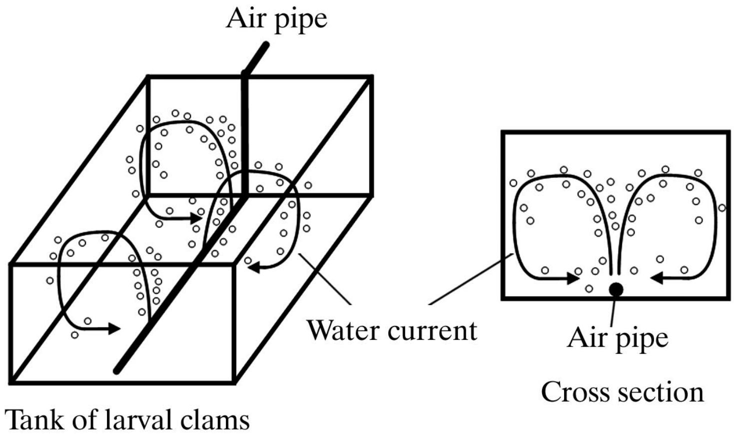


Fig. 10. Design of the 10-ton (2 × 5 × 1 m) and 5-ton tanks (1.2 × 4.0 × 1.0 m) showing water current direction to prevent dead spots in the tank.

is to take tissue directly from the mantle of live clams, mash it and separate the algae from tissue debris. Another method is to use cultivated algae maintained in artificial medium without aeration under white fluorescent light (about 60 μmol/m^2/s) with a 12:12-h light-dark cycle at 28°C.

After the zooxanthellae are provided, larvae should be observed every day. If no algae are visible in the gut of larval clams, they should be re-introduced. One half of the culture water is replaced at 2-3-day intervals. Many larvae settle and metamorphose from Day-7 and it is necessary to reduce aeration. Larval clams establish symbiotic relationship with algae between Day-10 and Day-20. It is possible to rear with no feeding once the symbiotic relationship is established. Many larvae die during this period. Average survival rate is 5% from D-shaped larvae to larvae with symbiotic relationship.

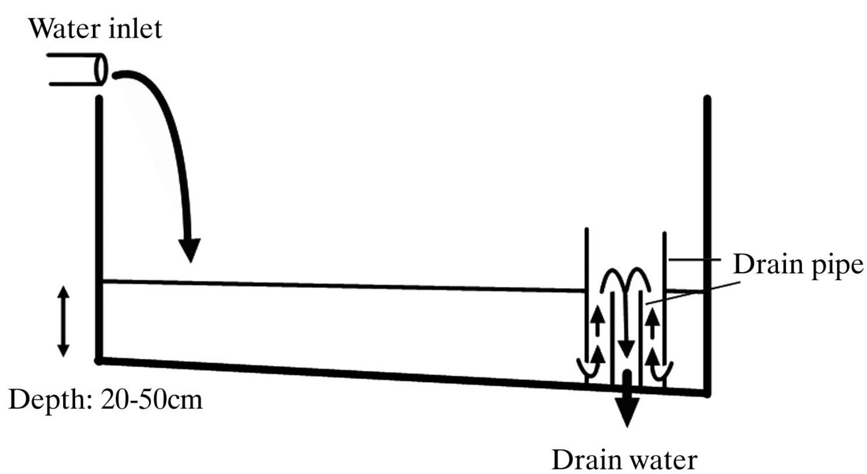


Fig. 11. Vertical section of the tank showing drainage of water from tank to prevent dead spots the bottom. The tank size is similar to that of Fig. 10.

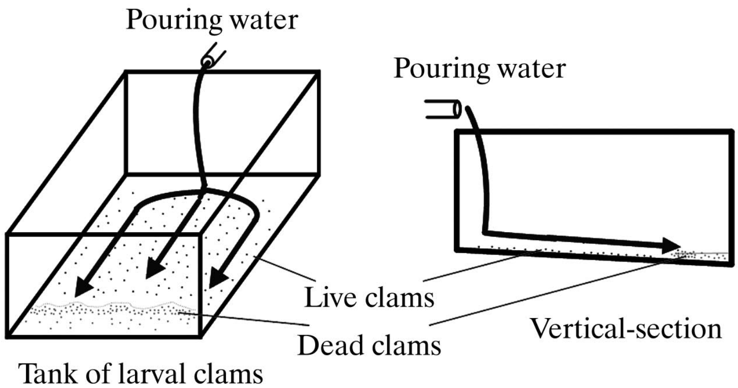


Fig. 12. Design of sweeping dead shells by pouring water in tank.

Flowthrough seawater (100-200% daily) is used as culture water and is kept at a shallow level (20-50 cm depth) after the establishment of symbiosis. Aeration is not used, to minimize the growth of weed in the tank. The bottom of the tank is drained using a large pipe sleeve with water inlets cut in its bottom then set over the drainage pipe (Fig. 11).

Growth of the larvae becomes stable with multiplication of the zooxanthellae in their mantle. Because the shells of larval clams are translucent, it is necessary to keep light intensity in the tank below 500 μmol/m^2/s by light shielding. The larvae grow to juveniles of 1 mm SL 2-3 months after fertilization. The light shielding should be gradually removed before the clams grow bigger than 1 mm SL. Suitable clam density at this stage is 10,000 ind/m^2.

If dead shells are found in large numbers at this period, they should be removed to avoid mass mortality. Dead shells can be swept by pouring seawater slowly over the bottom of the tank. After Day-50, live clams attach to the tank by means of their byssus (Fig. 13).

Juvenile clams bigger than 1 mm SL can be reared in direct sunlight in outdoor tanks. To clean weeds in the nursery tank, small herbivorous gastropods (*Batillaria* spp.) are reared with the clams. Small trochus (*Trochus niloticus*) are used as cleaning guests after the clams reach 3 mm SL because they are easier to rear than *Batillaria* spp. The feces of trochoids should be swept away routinely. Juveniles should be moved to a new tank at least every four weeks and the density maintained at a suitable level. This way, it takes about six months to a year for larval clams to grow to a size that can be used for aquaculture (i.e., 8 mm SL). Average survival rate is 0.3% from larvae to the utility size of 8 mm SL in Okinawa.

Aquaculture

Trochus crocea is generally cultured by planting the seeds in pits prepared by drilling in limestone substrates. The following three points are important for good aquaculture: a) site selection areas with a cover of sand or seaweed are not suitable; b) vertical boring into the substrate to minimize the ability of seeds to move away from the pits; and c) protection from predators by covering planted sites with nets to effectively protect clams against fishes or crabs, the major cause of mortality.

Trochus squamosa and *T. derasa* are cultured in cages fixed on the sea bottom.

The following points are important for good culture: a) selection of suitable site in shallow sea (2-5 m depth) and fixing the cage securely to prevent turning over during typhoons (Fig. 13-1); b) planting of bottom structure (e.g., coarse plastic mesh: Tamaki 2000) to prevent seed aggregation or clumping together that causes low survival; and c) maintenance of suitable culture conditions by cleaning the cage to secure sunlight and water supply (Fig. 13-2). The density of seeds in the cage should be maintained at 1000 ind/m^2 for 8 mm SL, and 300 ind/m^2 for 10 cm SL.

The market sizes in Okinawa are approximately 10-15 cm SL for *T. squamosa* and *T. derasa*, and 5-8 cm SL for *T. crocea*. Growth of the three species is shown in Fig. 14. At least two years are required to grow giant clams to market size. It is easy to rear giant clams because culture management does not require too much time as it needs only monthly or occasional monitoring. Survival rate is 40-50 % from utility seed size (8 mm SL) to market size. The utility size is based on the results of field tests (Tamaki 2000).

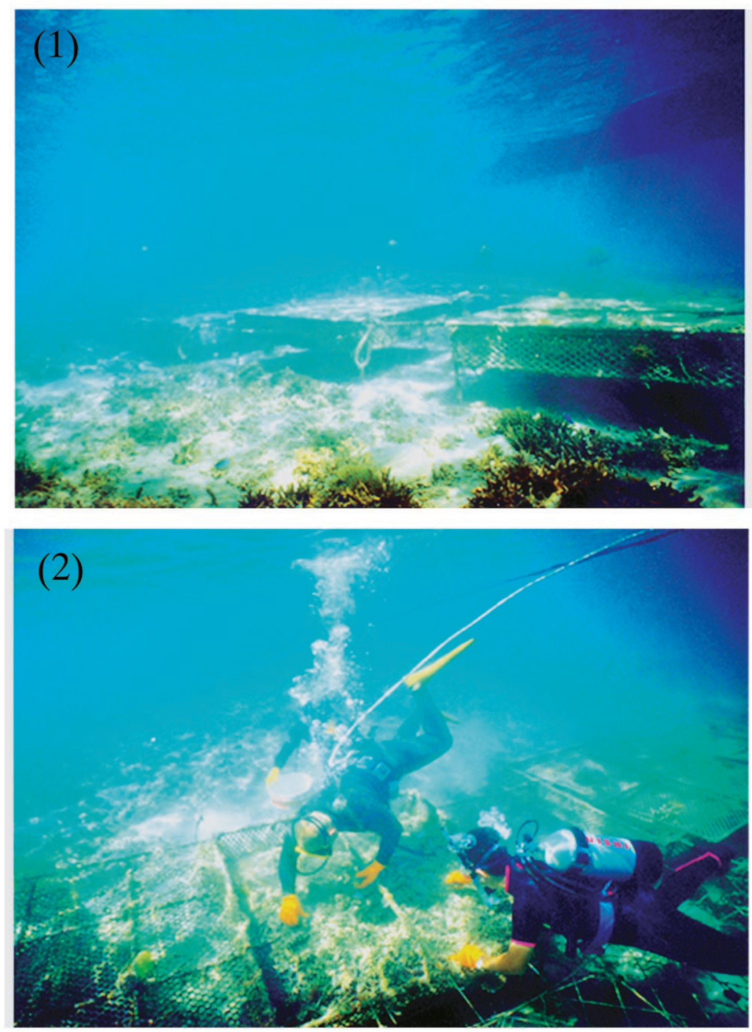


Fig. 13. Cage culture of giant clams in Okinawa, Japan: 1) set cages underwater, and 2) cleaning a cage.

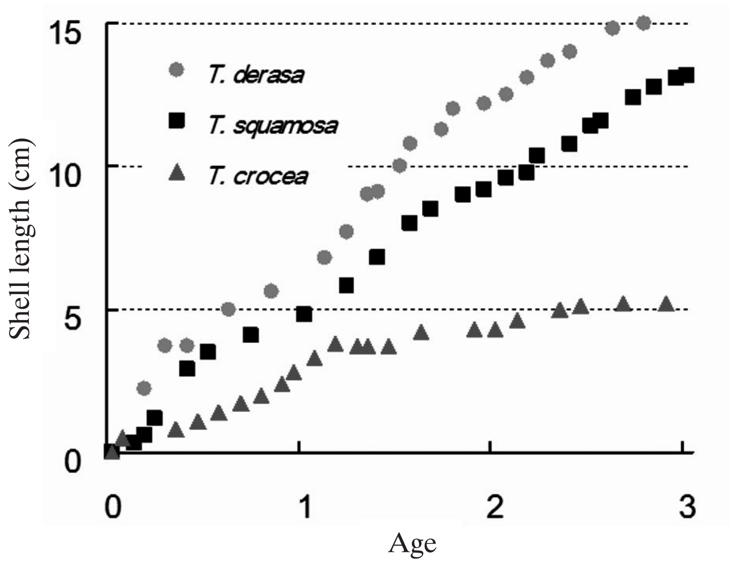


Fig. 14. Growth of three species of giant clams under culture conditions in Ishigaki Island, southern Japan.

Today, there is high demand in Okinawa for giant clams. Both the soft parts and the shells are utilized – the mantle and adductor muscles are mainly eaten raw while the shells are used for ornaments.

Other Studies on Giant Clams in Southern Japan

Heterozygosity of allozyme loci and usefulness as artificial seeds of giant clams have been studied by Kobayashi (2003). The proportion of soft part weight (SW) per whole body weight (BW) giant clam was positively correlated with the number of heterozygotic loci. More heterozygous individuals also achieved a higher proportion of SW/BW (%). For seed production, it is therefore necessary to prepare a large number of mature clams to allow the production of heterozygous progenies.

In the Yaeyama Branch of the Okinawa Prefectural Fisheries Experimental Station, the following three studies are ongoing: 1) practical effectiveness of resource management for giant clams verified in a marine protected area (MPA) in Okinawa where harvest of certain organisms is prohibited throughout the year; 2) seed production of *T. maxima* because the species is easy to rear in the winter season; and 3) artificial spawning for seed production in the winter season for seed distribution in summer when they are in high demand by fishermen.

The following two studies are planned at the Ishigaki Tropical Station, Seikai National Fisheries Research Institute, Fisheries Research Agency, Japan: 1) population genetic structure of clams in the islands in southern Japan to avoid genetic disturbance; and 2) factors in the establishment of symbiotic relationship for efficient seed production of giant clams.

The fishery regulation for stock management of giant clams in Okinawa bans harvesting of all species from June to August. Harvesting of *T. crocea* under 8 cm SL, *T. squamosa* under 20 cm SL, *T. derasa* under 30 cm SL, and *H. hippopus* under 15 cm SL is prohibited throughout the year. However, there is minimal enforcement of the rules by fishermen and locals. For sustainable utilization of giant clam resources, it is very important that the value of management and maintenance of fishing grounds is understood and recognized by fishermen and locals.

Acknowledgments

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Coral Culture and Transplantation and Restocking of Giant Clams in the Philippines

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Introduction

Philippine reefs are among the richest and most diverse in the world with more than 400 species of scleractinian corals identified (Veron 1995). In the 1970s, Philippine reefs started to be degraded and continued to decline mostly as a result of increasing demands placed on them by humans, and their misuse. Only about 5% of Philippine reefs have excellent cover (Gomez et al 1994, Wilkinson 2004).

The alarming degradation of coral reefs in many parts of the world has resulted in growing attention to coral reef rehabilitation using transplanted corals and other invertebrates (Edwards and Clark 1998, Rinkevich 2005). The idea of planting corals and restoring reefs goes back at least 30 years. Initial activities in the Philippines were accomplished through the collaborative efforts between the then UP Marine Sciences Center and Silliman University (Alcala et al 1982). It was also around this time that other countries, like the United States of America in Hawaii (Maragos 1974) and Australia in the Great Barrier Reef (Harriot and Fisk 1988) started their rehabilitation efforts. So the Philippines is among the countries that pioneered in reef rehabilitation work.

Another local coral transplantation effort was the Coral Farm Project (CFP) in Caw-oy, Cebu (1997 to 2000). It was initiated and supervised by the Marine Biology Section of the University of San Carlos in Cebu City and funded by the Commission on Higher Education – Center of Development Fund and the German Ministry of Environment facilitated by the Tropical Ecology Program of the German Technical Cooperation (Heeger and Sotto 2000). The objectives of the coral farm were to serve as a nursery for coral fragments, maintain biodiversity, and generate income for fisherfolk by marketing the farm-grown coral fragments for rehabilitation and ecotourism. The Caw-oy coral farm was two hectares in size with about 275 coral nursery units built by members of the Caw-oy Fisherfolk's Organization, containing about 22,000 coral fragments. Unfortunately, legal and sociological constraints put an end to this effort.

Recently, the Pew Project (2001 to 2005) of the senior author entitled "Coral reef habitat and productivity enhancement through coral transplantation and giant clam restocking" was implemented with the aim to improve the biodiversity and productivity of stressed coral reef habitats in 10 selected demonstration sites in the Philippines. These were meant to serve as models for other communities. Transplantation of corals and reseeding of giant clams were the approaches. Nubbins or small fragments from nearby large coral colonies and abundant solitary forms were transplanted to the target sites. Care was exercised to avoid or reduce any negative impacts on the natural source communities. Only cultured giant clams were used, specifically the threatened *Tridacna gigas* at sizes that would ensure their chances of survival in the wild (approximately 20-30 cm shell length). Following deployment, monitoring activities were undertaken, focusing on macro-invertebrates and fish, as well as the assessment of the survival and growth of experimental animals. Liaison work was

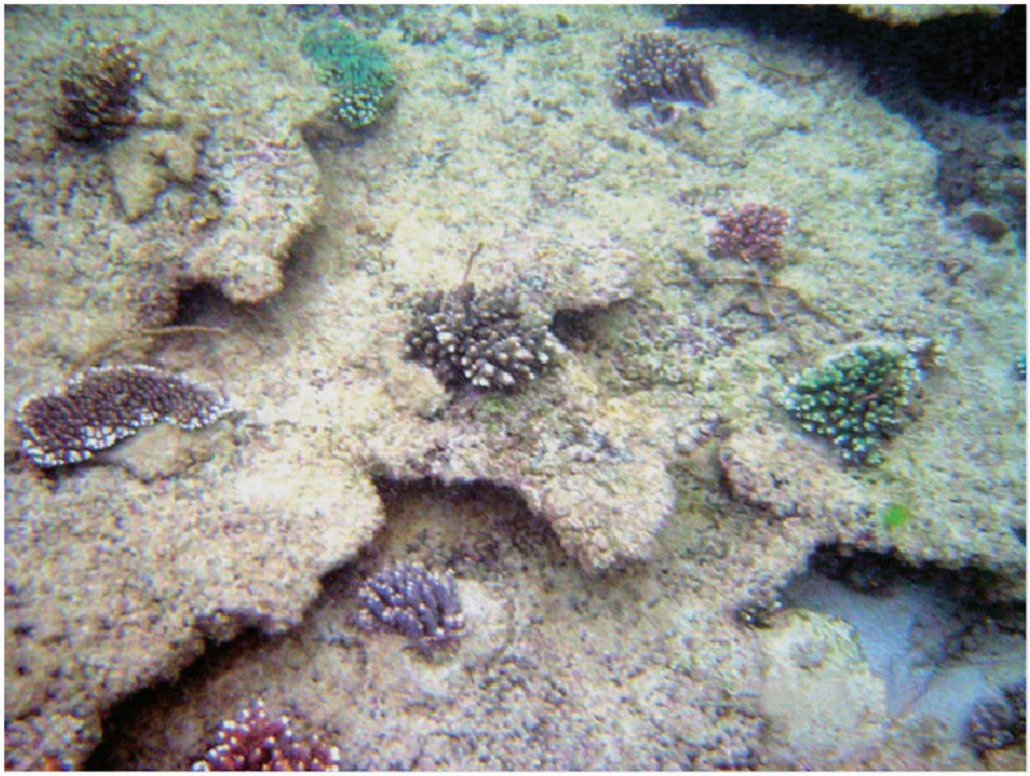

Fig. 1. *Acropora* spp. transplants cemented on dead table *Acropora* at Masinloc, Zambales (Dec. 2002 transplants).

done with local communities to raise their environmental awareness and to ensure their cooperation. This manuscript draws principally from results of the Pew Project.

At present, two other restoration projects supported by the European Union and the Global Environment Facility Coral Reef Targeted Research Project are being implemented at the Bolinao Marine Laboratory of the University of the Philippines–Marine Science Institute (UP-MSI) in Pangasinan. These projects are testing the efficiency of floating and standing coral nurseries in growing coral nubbins in addition to transplanting fragments or branches of corals to restore degraded coral reefs.

Approaches to Transplanting Corals

Direct transplantation on natural substrates

Cementing on dead reefal substrate

Cementing was the major method used in the Pew Project. This technique allows immediate firm attachment of corals on the natural substrate (Fig. 1). In collecting corals, natural broken fragments were picked up first before nubbins or small fragments were taken from locally occurring abundant, large coral colonies. Care was exercised to avoid or reduce any negative impacts on the natural communities by limiting harvest to only about 10% of the donor colony.

Months after the fragmentation, the source colonies were showing signs of recovery with new polyps forming and broken parts growing back (Fig. 2). To further check for collateral damage, the reproductive status of source colonies should also be monitored (Epstein et al 2001).

For cement preparation, a 1:3 ratio of cement to sand is usually mixed on shore. Then the final mixing with fresh water is conveniently done on the boat while on site. After adding enough fresh water to make a thick cement paste, the mixture is then placed inside plastic bags. Each plastic bag should be tightly tied, leaving no air inside and minimizing the entrance of seawater that may alter the semisolid property of the mixed cement during the actual transplantation underwater. Prior to application to the substrate, a small hole is torn off one corner of the bag just large enough to squeeze out the cement (like toothpaste). Depressions on bare, hard substrates with no living organisms is selected.

When a mound of cement is in place, the coral branch or fragment can then be embedded in the cement mound, and the cement molded gently around the coral base to form a good bond. The actual size of the cement mound depends on the size of the coral fragment with larger fragments requiring bigger mounds for firmer attachment, especially when using branching fragments.

In transplanting corals, fragments should be positioned upright towards the sunlight, so

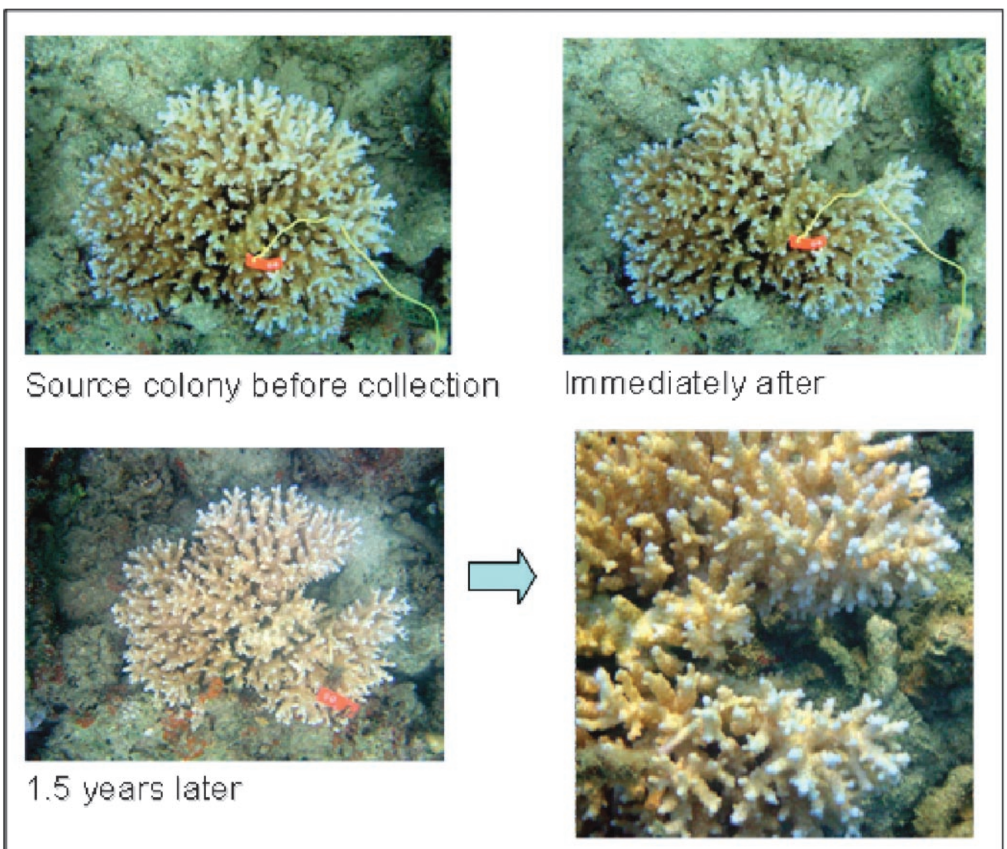

Fig. 2. Source coral colony at Alabat, Quezon showing recovery after fragmentation.

that they will grow naturally. It may be useful to brace the coral base by embedding some rocks or small pieces of rubble around the base. The cement base of the planted coral will become stable in about one hour after being placed underwater and will fully harden within 1-2 days.

The highest survival of coral transplants of about 84% was achieved in the site of Alcoy, Cebu, while the Camotes Is., Cebu site 1 obtained the lowest survival of 8% (Fig. 3). Mortality of coral fragments could be attributed to various causes such as predation by the crown-of-thorns starfish *Acanthaster planci*, burying of corals by sand, and dislodgment of transplants after a typhoon.

Tying to dead standing corals

Coral transplants may be tied directly to dead standing corals with the use of insulated copper wire (solid, #22). Dead corals should be large enough to support the coral fragment. This method reduces the disturbance brought about by sedimentation.

Relocation of solitary corals and of sub-colonies of staghorn thickets

Some reefs have areas where large monospecific thickets of corals are growing and clusters of solitary corals (fungiids) are found. Relocation of some of these corals on degraded reefs will minimize the spatial competition in the source areas. Thick branches of staghorn corals may be transplanted on sand where they are sometimes found naturally. On the other hand, the mushroom corals should preferably be relocated on hard substrates.

Use of giant clams

Using large tridacnid clams in the reef rehabilitation activities is a novel approach. This idea was derived from the observation that some of the giant clams restocked in the Hundred Islands National Park in Pangasinan province had been colonized by corals. The clams also offer a natural substrate for other invertebrates, in addition to corals and marine plants which subsequently attract grazers. Clams provide relief and structure, where fish and other invertebrates can take refuge and plants can grow. The most important reason for the use of clams in reef rehabilitation is to reestablish their breeding populations in strategic sites and eventually allow natural recruitment of juveniles to the reefs.

Transplantation on artificial substrates

Tying to terracotta tiles and marble chips

If suitable natural surfaces are limited, coral transplantation may be done on artificial substrates. One approach used in the project "Rehabilitation of the Hundred Islands National Park" was tying of coral fragments to marble chip rejects with the use of insulated copper wire. The marble chips were then fastened onto the natural substrate with concrete nails for permanent attachment. In the Coral Farm Project, corals were tied to terracotta tiles for restocking purposes (Heeger and Sotto 2000). Mortality among corals fastened to tiles often resulted from detachment or overturning.

Attachment to introduced boulders

Coral fragments may be transplanted to introduced boulders in areas such as extensive sand patches where hard substrate is limited. This approach was employed in Infanta, Quezon where some patch reefs are buried by sand from river run-off. Deployed boulders can stabilize the substrate and can also provide substrate for other fauna (Fox et al 2005). In Infanta, coral transplants were arranged around each boulder using nylon nets to hold them in

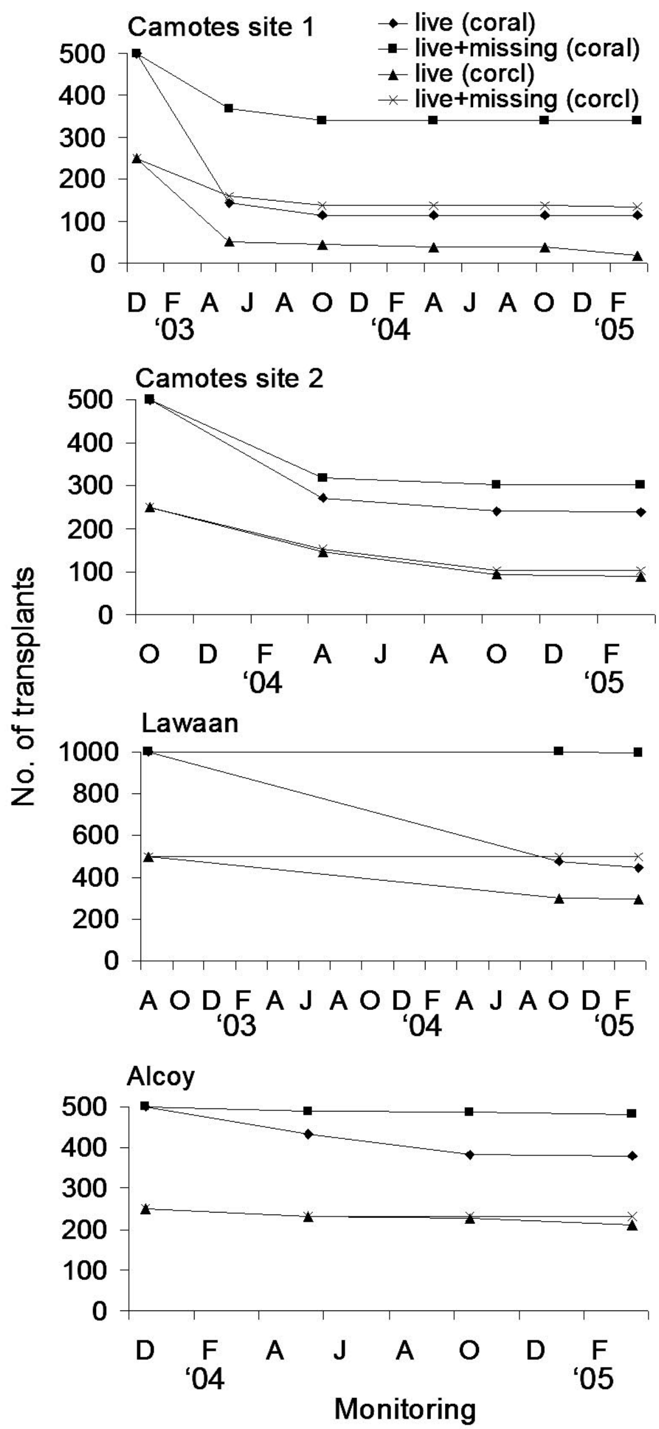

Fig. 3. Representative sites of the Pew Project showing highest (Alcoy: 84%) and lowest (Camotes 1: 8%) survival of coral transplants obtained. (Legend: coral = plots with coral transplants only; corcl = plots with corals and clams).

place until they could attach to the boulders. Alternate means of attachment such as underwater epoxy might also be tried. The use of boulders can add relief and structure to the reef where marine organisms can attach or take shelter.

Meshed grids for substrate stabilization

Another technique in substrate stabilization is the use of meshed grids. Stabilizing the substrate is a prerequisite to actual coral recruitment because unstable substrates can decrease the survival of both transplants and natural recruits. One collaborator in the Pew Project (L. Raymundo) used meshed plastic grids with cemented rock piles to stabilize rubble substrates. Preliminary results showed that the mesh remained fixed during stormy weather, though rock piles required additional cementing. Coral transplants showed 91% survival after one month. After 3 mo, obvious growth, natural attachment to the base and fusion between adjacent corals were observed. Coral recruits (1-2 cm diameter) also appeared on rock piles 4 mo after placement.

Coral farming

The inherent pressure on the source colonies during collection and the need for mass production of coral fragments for restoration create a need for coral farming. The first significant coral farming effort in the Philippines was the Coral Farm Project in Caw-oy, Cebu as earlier mentioned. Fragments were carefully chosen and cut from the donor colonies using pliers (for branching types) or hammer and chisel (for encrusting and massive types). The donor site was near the farm allowing the close monitoring of the health and impact on donor colonies after fragment collection and minimizing stress on the coral fragments caused by long transport. The collected fragments were tied firmly to terracotta tiles with galvanized iron wire, then transported to coral nursery units where they were left to regenerate and attach to the substrate. After three to four weeks, fragments were observed to have securely attached to the substrate. Monitoring and cleaning of sediment and algae from the coral nursery units were done regularly to obtain a higher survival rate of the transplants.

Another coral faming initiative at present is in Silaki Island, Bolinao, Pangasinan. Coral nubbins with a maximum size of 2 cm diameter or height were used. Nubbins were attached onto plastic meshed nets or plastic tubing, depending on the lifeforms, using cyanoacrylate adhesive. The method employed is similar to that described by Shafir et al (2006). The plastic meshed nets and plastic tubing with corals are then secured to the floating or standing coral nursery platforms. These field-reared coral nubbins will be used to rehabilitate damaged reefs in the future. The nursery method also has great potential for the culture of corals for the aquarium trade. In addition to the use of nubbins, future nurseries may also use coral planulae produced by spawning induction or collected from the wild (Heyward et al 2002).

Restocking of Giant Clams

Giant clams (Family Tridacnidae) are essential components of the coral reef ecosystem and contribute to reef production. They are primary producers because of the presence of their algal symbionts, supporting various marine organisms by serving as nursery grounds of numerous invertebrates and fishes when present in large numbers. Their calcified shells are good substrata for sedentary organisms thus contributing to reef diversity. Tridacnids are exploited for their meat and shells to various degrees in the Indo-Pacific region, their distribution range. In the Philippines, giant clam meat is utilized as food and is

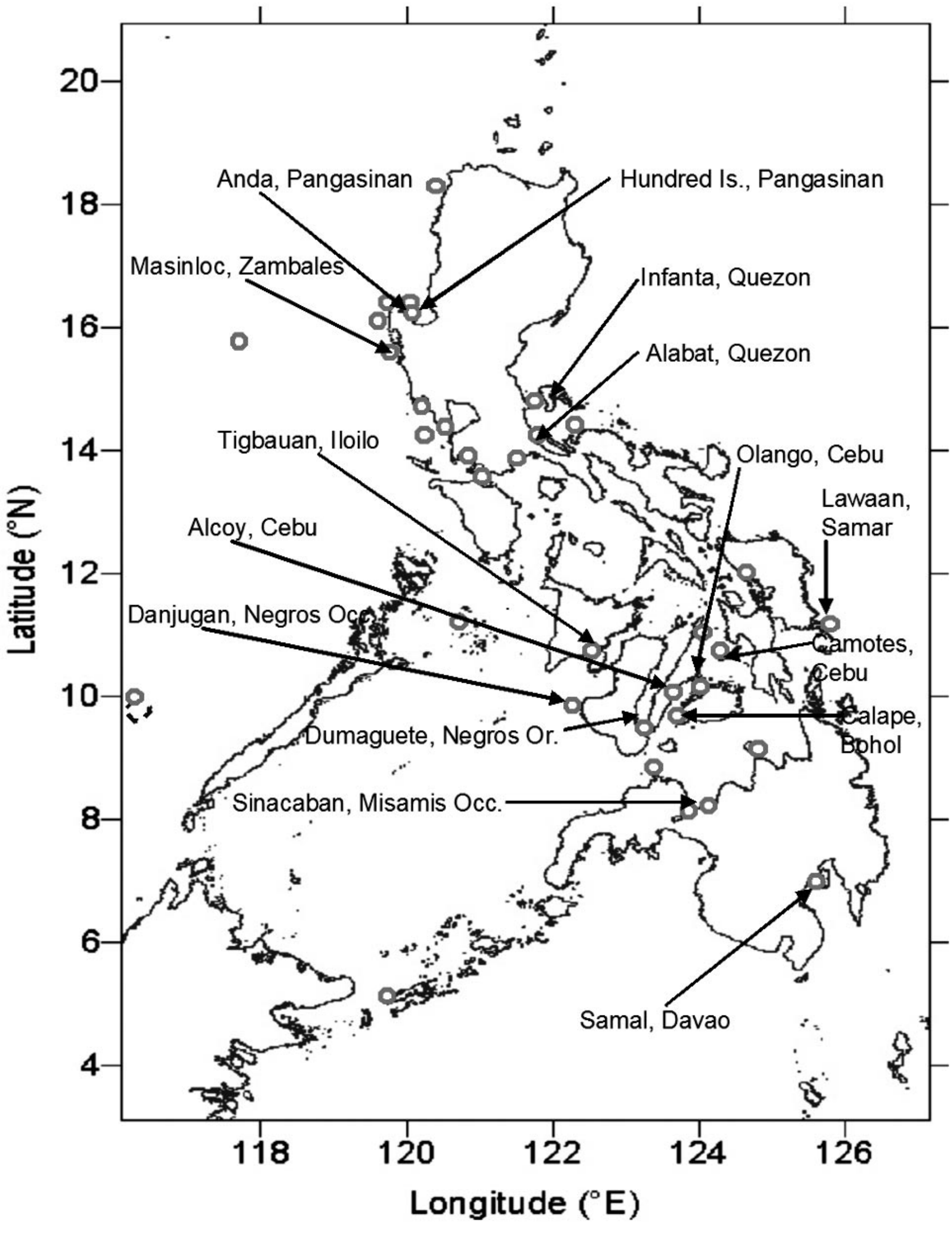

Fig. 4. Location map of the Pew Project demonstration sites for coral transplants, the Hundred Islands National Park, and sites of giant clam culture.

being sold in local markets. Overexploitation has resulted in the scarcity of most of the indigenous species.

The remaining giant clam populations are threatened by commercial exploitation, poaching, illegal fishing practices that degrade their habitats, bleaching, disease, and pollution (Mingoa-Licuanan and Gomez 2002). Due to intense use of giant clams, harvesting natural clam stocks is no longer sustainable. As a result, there is a need to culture these bivalves to supply clam seeds for restocking purposes and to provide alternative source of clams for the demands of commercial trade. It is important that the remaining wild stocks should be allowed to recover, either naturally or by restocking of cultured seed stocks.

Conservation efforts to restore giant clam populations are being practiced in the Philippines by the UP-MSI. In the 1980s, the WorldFish Center (then ICLARM, the International Center for Living Aquatic Resources Management) and the Australian Centre for International Agricultural Research (ACIAR) organized a regional collaborative research program whose key objectives were to establish tridacnid broodstocks and develop mariculture technology. The ensuing six-year program involved Australia, several South Pacific island nations, and the Philippines with the UP–MSI as one of two participating academic institutions in the country. A publication from this program (Copland and Lucas 1988) provides an overview of giant clam biology and culture.

Obtaining broodstock was not easy because the three largest species, *Tridacna gigas*, *T. derasa* and *Hippopus porcellanus*, were uncommon. The small burrowing species, *T. maxima* and *T. crocea* were still abundant while *T. squamosa* and *H. hippopus*, could be found in good numbers only in certain localities (Juinio et al 1989).

Between 1989 and 1994, the UP–MSI was able to collect adequate numbers of *H. hippopus*, *T. squamosa*, *T. maxima* and *T. crocea* for experiments on spawning. Of the rare species, three cohorts of *T. derasa* seed were imported from Palau between 1984 and 1985; and seven cohorts of cultured *T. gigas* were imported from the Solomon Islands (as pediveligers) and from Australia (as juveniles) and between 1987 and 1995.

The UP–MSI has been able to culture the six species mentioned above. Lack of *H. porcellanus* broodstock did not allow UP–MSI to culture this species successfully, though the technology is available.

When funding from ACIAR terminated in 1992, MSI continued work on the culture of giant clams with support from the International Development Research Centre (IDRC) of Canada. Its objectives were to mass produce juveniles for restocking purposes and to create livelihood programs through giant clam farming. With the success of giant clam rearing, UP-MSI started to restock in various parts of the country focusing on the largest tridacnid, *T. gigas*.

In 2001, the program received significant support through the Pew Marine Conservation Fellowship for the senior author. The project "Coral Reef Habitat and Productivity Enhancement" aimed to improve the biodiversity and productivity of degraded coral reef habitats in ten selected demonstration sites in the Philippines through coral transplantation and giant clam reseeding, particularly the threatened *T. gigas*. A total of 1,125 sub-adult clams were deployed in 11 demonstration sites (one site added to the 10 sites originally proposed) and about 10,145 juvenile clams were transported to other sites for rearing (Table 1 and Fig. 4).

An earlier clam restocking project in the Hundred Islands National Park funded and

Table 1. *Tridacna gigas* and *Hippopus hippopus* clams distributed through the Pew Project, 2002-2004.

Demonstration sites (sub-adult clams)	**Quantity**	**Other sites (juvenile clams)**	**Quantity**
Northern Philippines			
Anda, Pangasinan	225		
Masinloc, Zambales	225		
Infanta, Quezon	75		
Alabat, Quezon	75		
Central Philippines			
Alcoy, Cebu	75	Tigbauan, Iloilo	500
Camotes, Cebu	150	Danjugan, Negros Occ.	500
Calape, Bohol	75	Dumaguete, Negros Or.	5000
Lawaan, Eastern Samar	75	Olango, Cebu	1250
		Lawaan, Eastern Samar	2350
Southern Philippines		Sinacaban, Misamis Occ. (sub-adults)	25
Samal Island, Davao	150	Samal Island, Davao	520
Total (all *T. gigas*)	1125	Total (all *T. gigas* + 40 *H. hippopus*)	10145
Approx. survival of sub-adults	92%	Approx. survival of juveniles	15%

supported the Philippine Tourism Authority had for its main objective the establishment of giant clam ocean nurseries as demonstration sites for clam conservation. At the end of that project in 2002, about 10,000 giant clams of various sizes had been deployed in different sites in the park. See Gomez and Licuanan (in press) for a full account of this effort.

Constraints

In the Philippines, it is unfortunate that present government policies do not allow commercial production of corals and the export of both corals and giant clams for the aquarium trade, even if they are cultured. This results from a misunderstanding of CITES regulations. Both scleractinian corals and giant clams are listed in Appendix II of the Convention, which means that their international trade should be managed, but not prohibited.

It is noteworthy that other countries, notably Indonesia, trade both wild collected and cultured corals, while other countries such as the Solomon Islands and the Marshall Islands trade cultured clams in the international market. This simply means that the Philippines is missing an opportunity to help coastal inhabitants develop an alternative livelihood, unless the laws and regulations are modified. There is no valid reason for countries not to engage in appropriate coral and giant clam culture and trade.

There is a need to improve the techniques briefly described here. A few manuals already exist for coral restoration (e.g., Omori and Fujiwara 2004) which outline some of the culture approaches. Fortunately, there are two ongoing initiatives on coral restoration that are being funded by the Global Environment Facility and the European Union. In a few years, the state of the art in coral culture and transplantation should be significantly improved. For giant clams, the culture techniques have been in existence for the past two decades.

Acknowledgements

We wish to thank SEAFDEC/AQD for the invitation to the senior author to participate in the workshop on stock enhancement. Much of this work is derived from the project, "Coral reef habitat and productivity enhancement through coral transplantation and giant clam restocking", of the senior author, a Pew Fellow in Marine Conservation. This paper is UP–MSI Contribution No. 348.

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Community-Based Stock Enhancement of Topshell in Honda Bay, Palawan, Philippines

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Introduction

Many coral reefs are located nearshore, hence they are readily accessible to exploitation by coastal dwellers. This makes reef resources vulnerable to over collecting, especially shells which are either slow moving or sessile. Depleted populations of valuable shells are difficult to restore because their growth rate is slow (Nash 1985) and the larvae have relatively short planktonic life that limits the range of their distribution (Heslinga 1981). Depletion of coral reef and associated resources due to unregulated or poorly regulated harvesting is of increasing concern not only in the Philippines, but also in the Indo-West Pacific.

In Palawan, Philippines, observed reduction of trochus shell resource in various areas was due to unregulated harvest mainly by compressor (hookah) divers and free diving fishers from other provinces. The latter migrate to Honda Bay for greater livelihood prospects (Gonzales 2004), increasing the population of coastal communities along the Bay. According to fishers in Honda Bay, their shellfish resources were bountiful until traders and divers from other parts of the country came to Palawan in the 1970s, depleting topshell *Trochus niloticus* and other species.

One of the objectives of Coastal Resource Management (CRM) is the regeneration of depleted resources and their sustainable use. On the other hand, the socio-economic objectives are: a) to alleviate poverty in coastal communities through added income and, b) to encourage responsible use of coastal resources through active participation of coastal communities in decision-making, planning, and implementation.

In the above context, both objectives could be attained through restocking or stock enhancement (Gonzales 2002a; Bell and Garces 2004) using community based-CRM approaches, where populations of severely overexploited resources are restored through active participation of local governments and communities. Hence Community-Based Stock Enhancement (CBSE) was introduced as a CRM strategy. The community-based topshell stock enhancement in Barangay Binduyan was assisted by the Fisheries Resource Management Project (FRMP) of the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture (DA-BFAR).

The objectives of this paper are to: 1) describe the processes in a community-managed stock enhancement project; 2) document monitoring and evaluation of the project; and 3) give recommendations to improve future community-managed stock enhancement project.

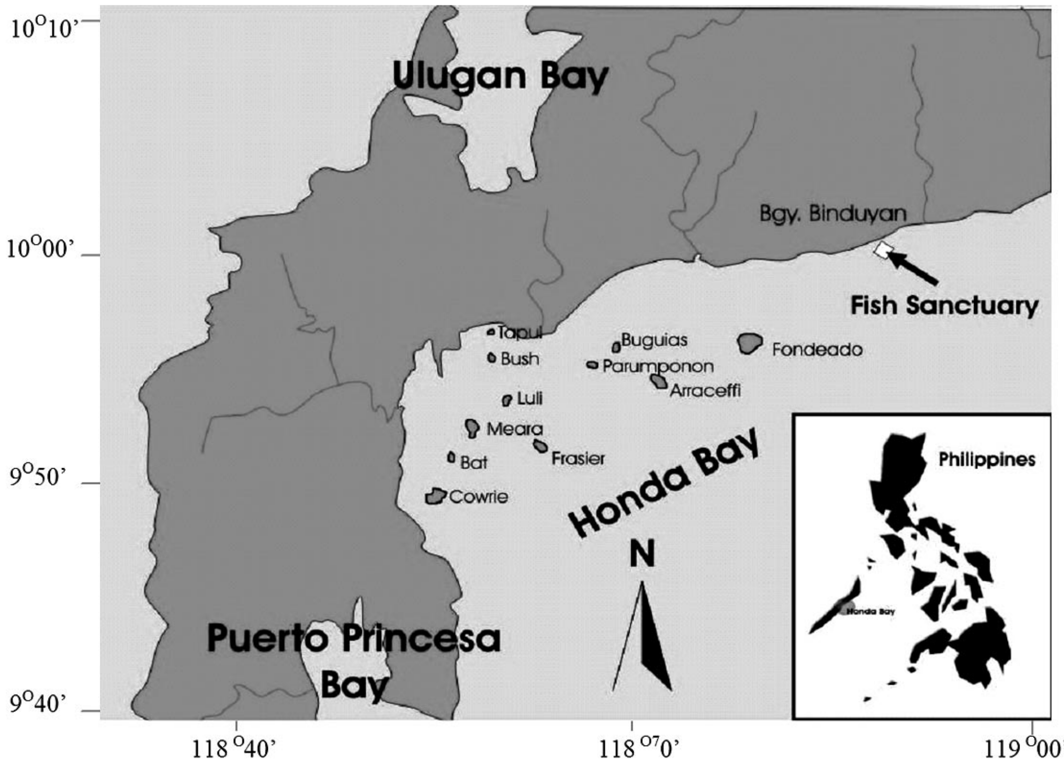

Fig. 1. Map of the Philippines (inset) and Honda Bay showing location of study site, fish sanctuary in Bgy. Binduyan, Palawan City, Puerto Princesa.

Topshell

Native to countries of the Western Pacific, the topshell has been introduced to many locations throughout the Pacific Islands (Smith 1987). This shell is collected and exported for button making, jewelry, and other decorative items (Mcgowan 1970) while the meat is processed by salting or smoking, thereby providing an important source of income for rural fishing communities.

In recent years, the market value of trochus shell has increased markedly, hence the level of exploitation has also increased in many Pacific Island countries. It is feared that present levels of harvesting will not be sustainable with serious resource depletion if management regimes are not instituted. Depletion of trochus shell due to unregulated harvest has been observed in various areas in the Philippines (Gonzales 2005).

The World Conservation Union (IUCN) has placed *T. niloticus* on its list of commercially threatened invertebrates. In the Philippines, this species was classified under highly regulated shells under Fisheries Adm. Order 157 and Fish Game Adm. Order 11, but is now categorized by Fisheries Adm. Ordinance 208 (May 2001) as a threatened species whose catch or collection is prohibited.

The selection of species of the Bureau of Fisheries and Aquatic Resources-Fisheries Resource Management Project (BFAR-FRMP) was based on information that topshell resources are depleted in Sabang Reef, Palawan because many fishermen collect topshells for livelihood. Moreover, a survey revealed that the fish sanctuary in Sabang Reef is a natural habitat for topshells, and lastly, there is a topshell hatchery in the locality. The selection of topshell also followed the species selection criteria developed by BFAR-FRMP (Gonzales 2005). These criteria are biodiversity, technology, socioeconomics, and research.

Materials and Methods

The project site is located in Bgy. Binduyan and Sabang Reef in Honda Bay, Palawan in western Philippines (Fig. 1). Data on the stock enhancement effort were obtained from management plans, minutes of *barangay* (village) meetings, city ordinances and barangay resolutions, assessment and survey reports, BFAR-FRMP reports, interviews and personal observations.

The impact assessment survey was done from July to October 2004. The assessment was conducted pre- and post- intervention in both impact and control areas for biophysical changes in time and location (Osenberg and Schmitt 1996).

Two methods were used to determine abundance, distribution, and sizes of topshells inside and outside the fish sanctuary – the permanent quadrat and belt transect (English et al. 1997) with slight modifications (Galon et al. in press). Two 5 x 200 m belt transects were used in deep water stations both inside and outside the fish sanctuary, while one 20 x 200 m quadrat was used in intertidal stations of both inside and outside the fish sanctuary. Surveys were conducted using SCUBA in the deep-water station, and by walking inside the quadrat of the intertidal stations (Figs. 2 and 3).

The sociological survey was based on interviews of 70 respondents (of a total 77 fishermen in Binduyan) to evaluate the impact of the restocking initiative using indicators such as change in size of gleaning area, length of time spent gleaning, abundance and size of gleaned shells, and awareness and attitudes toward restocking and protection.

Results of the interview were pooled together and a descriptive analysis of the data was done. The responses of the members of the community were described through percentage.

Fig. 2. Measuring basal diameter of topshell.

Results and Discussion

Chronological events

The chronology of events in the establishment of the fish sanctuary, and community preparations for the stock enhancement project are listed in Table 1 starting with social and technical preparations in 1999 up to project evaluation in 2004.

The passing of the ordinance for the sanctuary declaration took time due to the modification of the shape and area of the sanctuary. Additionally, changes in the political leadership affected activities in the field.

The Barangay Council passed a resolution to implement stock enhancement only after the training was conducted. When community members recognized the value and importance of topshell stock enhancement, the project should have strengthened its community information and education efforts.

Surveys of potential release reefs and microhabitat sites were conducted prior to actual experimental releases of juvenile topshells (Table 1) (Gonzales 2002b). Presentation of such results to the community helped explain the condition of their resources and the benefits of stock enhancement.

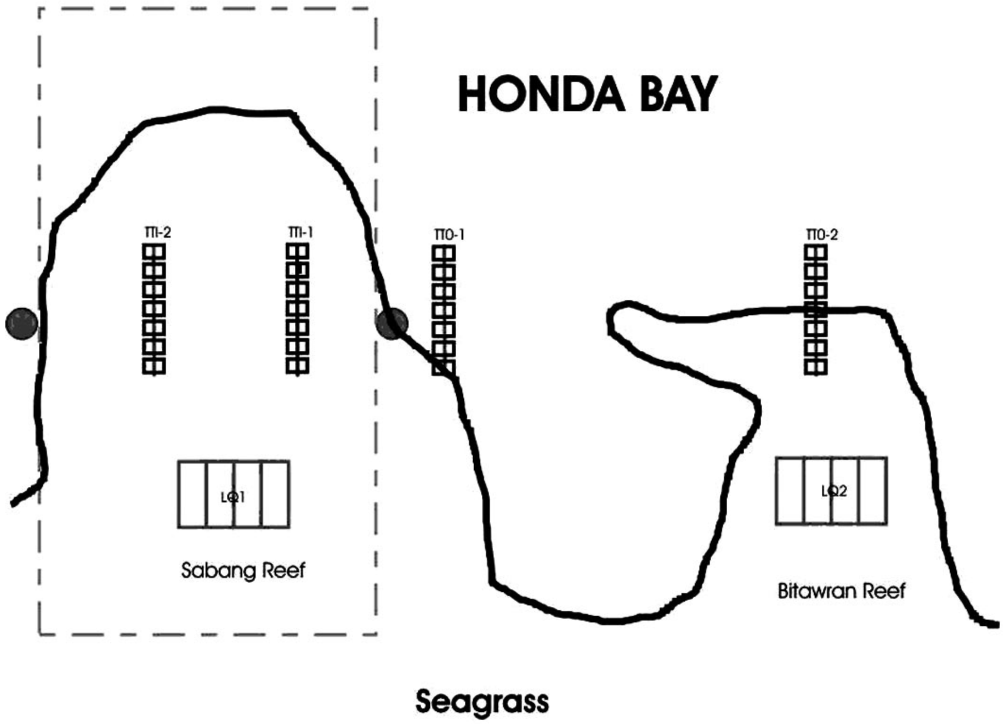

Fig. 3. Location of quadrats in intertidal and belt transects in deepwater stations for topshell density assessment in protected (Sabang Reef) and unprotected (Bitawran Reef) areas. TTI-1 represents Traverse Transect Inside no. 1; TT1-2, Traverse Transect Inside no. 2; TTO-1, Traverse Transect Outside no.1; TTO-2, Traverse Transect Outside no. 2; LQ1, Low water Quadrat no. 1; LQ2, Low water Quadrat no. 2.

Juvenile topshells donated by the Iris Marine Development Corp. (operator of topshell hatchery) were released in the Sabang Reef Fish Sanctuary during the launching and end–of–stock enhancement trainings. Community members and partners were enjoined to participate in the releases not only to learn skills but also to encourage commitment to the project.

Two markers were tested on released juvenile topshells. Plastic markers glued to the shell (using marine epoxy) lasted not more than three months. Some shells were recovered without tags but with remains of the epoxy glue. The diet tag formulated by SEAFDEC/AQD (see Okuzawa et al, this volume) proved more reliable than the glued plastic. However, the local hatchery cannot afford to produce this tag because it requires 24 h running water, and the hatchery has electrical power only during the day.

Groundwork to sustainability

The Participatory Coastal Resource Assessment (PCRA), which requires the active participation of stakeholders in information gathering and analysis prior to planning and management, was used. The Sanctuary Management Board (SMB) of Bgy. Binduyan was empowered through training, onsite practicum, and close assistance in the development and implementation of the Fish Sanctuary Management Plan and Stock Enhancement Management Plan.

Table 1. Main chronological events in the establishment of fish sanctuary and implementation of community-managed stock enhancement in Bgy. Binduyan, Palawan City, Puerto Princesa.

Event	Date	Remarks
REA for site selection	6 Sept. 1999	BFAR divers
Public hearing	11 Oct. 1999	City Agriculture Office
Training on Establishment and Management of Fish Sanctuary	23-25 Aug. 2000	Project Consultants and City Government
Signing of City Fisheries Ordinance No. 192	11 Feb. 2002	City Council passed Ordinance
Development of IRR for fish sanctuary	23 May 2002	Morning session -Fish sanctuary and topshell management workshop
Workshop on Agreements on the Implementation and Management of Topshell Stock Enhancement	23 May 2002	Afternoon session - Fish sanctuary and topshell management workshop
Election of SMB officers, presentation of site baseline assessment results to the community	May to July 2002	Haribon-Palawan, BFAR-FRMP, City Government, Iris Marine Dev. Corp.
Survey of release sites in fish sanctuary and setting up of marker buoys	20-22 May 2002	SMB, Barangay Council, FRMP, Haribon-Palawan, CAO
Ceremonial release of juvenile topshells	24 July 2002	SMB, BFAR-FRMP, Iris Marine Dev. Corp
Induction of SMB Officers	26 July2002	BFAR-RO-IVB, FRMP, CAO, Iris Marine Dev. Corp.
Launching of fish sanctuary and topshell stock enhancement projects	27 July 2002	BFAR-RO-IVB, FRMP, CAO
Training on Sanctuary and *Trochus* Shell Management, practicum on topshell release and monitoring	18-20 Feb. 2003	SEAFDEC/AQD researchers, BFAR-FRMP
Binduyan Barangay Council approval of Topshell Stock Enhancement Project	1 Aug. 2003	Resolution passed by Barangay Council
Assessment of CBSE impacts	July-Sept. 2004	FRMP, Western Philippines Univ., CAO, Haribon-Palawan

REA - Resource Ecological Assessment; BFAR - Bureau of Fisheries and Aquatic Resources; FRMP - Fisheries Resource Management Project; RO - IVB - Regional Office No. 4B, CAO - City Agriculture Office; IRR - Implementing Rules and Regulations; SMB - Sanctuary Management Board; SEAFDEC/AQD - Southeast Asian Fisheries Development Center, Aquaculture Department; CBSE - Community - Based Stock Enhancement

Establishing partnerships, identifying counterparts, and sharing were applied in every activity to instill in the community the sense of responsibility, accountability, ownership, and sustainable operation of the CBSE. After completion of the project, the community partners (City Government, academe, private sector, and NGO) are expected to continue stock enhancement activities.

The Sanctuary Management Board made the Stock Enhancement Project Agreements during the Workshop on Implementation and Management of Topshell *Trochus niloticus* Restocking in Sabang Reef Fish Sanctuary, Bgy. Binduyan, Puerto Princesa City, 23 May 2002.

In the workshop, it was agreed that the collection of re-stocked shells will be 4-5 years later (2006) and only shells with diameter of 7.6 cm and above shall be collected outside the core zone.

Shell collection shall be for six months per year only, from July to December. The area will be closed for harvest from January to June. Collectors will be divided into six groups and will be allowed to gather shells in certain areas to be identified by SMB. The volume of harvest will also be determined by SMB.

Gleaning of topshells is prohibited even outside the release area (FAO 208), unless clearance and proper permits are obtained. Collectors must register with the SMB, and the Secretary shall facilitate registration.

Harvest of re-stocked shells is exclusive to Binduyan residents, especially fisherfolk while the Iris Marine Development Corporation will buy the harvested topshell.

In terms of benefits and beneficiaries, the stakeholders agreed that an area would be reserved for the youth sector (15 years and below). On the other hand, women and tribal members will be hired by the Iris Marine Development Corporation to extract and process topshell meat.

It was also proposed that a) barangay tax of PhP2/kg will be collected from the topshell gatherers. PhP1 will go to the barangay and the remaining PhP1 will be used for the operations and maintenance of the CBSE project. The suggested selling price of topshell will be less 10% of the prevailing price when sold to Iris Marine Development Corp.

Community-based stock enhancement impact assessment

Biophysical

In the intertidal area, results indicate that the abundance and sizes of topshell (Table 2) in the protected area (4.58 cm) are significantly bigger ($t=2.03$, $p=0.05$, $n=39$) than those in the unprotected area (2.95 cm).

In the deepwater stations, no topshells were observed in the unprotected area whereas in the protected area, topshells had a density of 190.0 ind/ha and mean basal diameter of 10.63 cm. In the intertidal area, the density was 70.0 ind/ha and 27.5 ind/ha in the protected and unprotected areas, respectively.

Data from the Iris Marine Development Corp. showed that topshells in deepwater stations had a mean basal diameter of 4.98 cm (range: 4.6-7.4 cm) in 2002 and 9.59 cm (range 8.30-11.20 cm) in 2003 (Table 3).

Analysis of variance revealed that the mean basal diameter of topshells was significantly greater in 2003 and 2004 than in 2002.

The density of topshells in the protected intertidal area of the sanctuary increased significantly from 40 ind/ha in May 2002 to 70 ind/ha in September 2004 (Table 3),

Table 2. Size and abundance of topshells in protected/unprotected, and intertidal/deep water stations (values in parentheses are ranges).

Size and abundance	**Intertidal (0-2 m)**		**Deepwater (4-21 m)**	
	Protected	Unprotected	Protected	Unprotected
Mean basal diameter ± SD (cm)	4.58 ± 1.43 (2.00-6.70)	2.95 ± 1.24 (1.00-4.90)	10.63 ± 0.57 (6.50-16.50)	none
Density (ind/ha)	70.00	27.50	190.00	0.00

an increase of 75%. The size of topshell (mean basal diameter) however did not change.

Sizes of topshell in the deep water station were significantly higher after restocking was implemented. Mean basal diameter increased from 4.98 cm in September 2002 to 9.59 cm in 2003 and 10.63 cm in 2004.

Sociological

A survey administered by interview (n=70 respondents) evaluated the sociological impact of restocking in the protected area. Majority (71%) of the respondents believed that their gleaning area remained the same size while 19% said they had a wider area. However, 9% of the respondents believed that restocking and protection encroached on their gleaning area.

The length of time spent for gleaning decreased for 37% of the respondents, increased for 31%, but remained the same for the remaining 31%. About the changes in abundance of topshells, majority (70%) said they gleaned more topshells after the restocking effort, 9% were gleaning less topshells, and 17% observed no change. Majority (61%) of respondents believed the size of topshells increased, 19% reported no change, and 20% did not respond.

Almost all (96%) of the respondents knew that topshells were being released in the protected area; only 3% were not aware of the initiative. Of those who knew about the initiative, only 89% were aware of the prohibition in gathering topshells, 7% were not aware, and 4% had no response. Almost all (94%) of the respondents were in favor of the prohibition. Because some gleaners claim they cannot distinguish juvenile topshells from other similar shells, identification should also be included in the training.

Coral reef sanctuaries for *Trochus* shells

Using the community–based approach to stock enhancement, Meñez et al (1998) recommended limited exclusive use of an area for grow-out culture or stock enhance-

Table 3. Population density and sizes of topshell from 2002 (before stocking) to 2004 (after restocking) (data from Iris Marine Development Corp.).

Year	**Intertidal Station (0-2 m)**	**Deep Station (4–21 m)**		
		Basal diameter (cm)		
	Density (ind/ha)	Mean ± S.D.	Minimum	Maximum
2002	40	4.98 ± 0.54	4.60	7.40
2003	no available data	9.59 ± 0.58	8.30	11.20
2004	70	10.63 ± 0.57	6.50	16.50

ment of the sea urchin *Tripneustes gratilla*. This approach has been encouraged by Heslinga et al (1984) and applied in this study. The data in this study validate the perceptions of the community that restocking combined with protection generally improves livelihood because they are now gleaning more and bigger topshells.

The community-based approach has led to the establishment of a fish sanctuary with legal framework for law enforcement, and has motivated the community to create other law enforcement schemes to protect the sanctuary. Nevertheless, gleaning of juvenile topshells continued and SMB has apprehended five violators.

Impact assessment

Topshell density of 190 ind/ha in the protected area in Honda Bay is comparable to other areas in the Pacific Region – the maximum population of topshell in a barrier reef in Chuuk State, Micronesia was only 37 ind/ha (Gawel 1997). Mean density of mature topshells was 80 ind/ha in Okinawa, Japan (Isa et al 1997); and 45 ind/ha in Papua New Guinea (DFMR 1997). Mean density of topshell was 556 ind/ha in the inter-island channels and 962 ind/ha on reef flats in the Marshall Islands (Kilma and Kobaia 1997).

The absence of mature topshells in the deeper waters of the unprotected area, even in the survey area just outside of the sanctuary, reflects the extent of harvesting of the resource. Despite awareness among 94% of the fishermen/respondents about regulations prohibiting topshell gathering, results indicate that harvesting continues unabated. The present study also confirms previous findings of Becira et al (in press) in the same site that topshells were conspicuously absent outside the protected area.

Although the community-based stock enhancement approach has contributed to restoring topshell populations inside the protected area, it has to be evaluated in terms of economic returns. Economic evaluation was not included in the present study because of insufficient data. Additionally, Fisheries Administrative Order 208 (prohibiting topshell collection) allows free trading of topshell, making economic analysis difficult. Since the project is in its introductory phase, future refinements will improve restoration of resources and economic benefits. Data collection should continue as the project progresses and processes shall be fine-tuned.

Conclusions

The Fish Sanctuary and the CBSE Project have addressed the following issues and concerns at different degrees as expressed by the Binduyan community during the 1999 Planning Workshop: 1) lack of alternative livelihood, 2) illegal fishing and weak law enforcement, 3) destruction of coastal habitats, and 4) intrusion of commercial fishing boats in municipal waters. The project has improved topshell resources and livelihoods by increasing topshell numbers and sizes, and also community awareness and attitudes towards restocking and protection. These results imply that the community-based stock enhancement approach is a potential tool for coastal resource management. However, continued harvesting of topshell despite the apparent benefits and prohibitions suggests that partners and environmentally–conscious community members should continue information and education activities, while maintaining law enforcement.

This paper is the first to document the processes used in a community-managed stock enhancement project. Nevertheless, some constraints have to be resolved for the improvement of CBSE technology. It may be advantageous to learn from the lessons of more advanced community-based coastal resource management projects implemented in other parts of the Philippines (Northern Luzon, Visayas) and around the world.

Recommendations to improve future community-based stock enhancement projects

These recommendations are based on the stock enhancement experiences in Palawan and other BFAR Regional Offices apart from Region 4B, and from the results of three national FRMP workshops on marine stock enhancement in the Philippines (2003-2005).

1. Species selection
   a. Define selection criteria, including native species
   b. Consult stakeholders and experts
   c. Consider socioeconomic and biological aspects of species
   d. Consider available technology for captive spawning and rearing
   e. Consider available technology for transport, release, and monitoring
   f. Know the conservation status of the species

2. Selecting release sites
   a. Adequate food and shelter; free from heavy siltation, pollution, destructive methods of fishing, etc.
   b. Area large enough to accommodate released seeds
   c. Available habitat protection (preferably MPAs with multiple zones), fish sanctuaries, core zone or No Touch zone of MPA with effective law enforcement

3. Release of organisms
   a. Participation of stakeholders
   b. Release of hatchery-bred individuals or individuals from the wild in No Take zone of MPAs
   c. Plan the release activity, e. g., size and density of release individuals, timing and site of release
   d. Surface and bottom markers at release sites

4. Management
   a. Use adaptive management that deals with current problems and issues through re-planning process, done regularly
   b. Use integrated management approach that facilitates sharing of responsibilities and accountabilities among various agencies: government, community, private sector, etc.
   c. Set up a management body
   d. Financial, scientific, and technical support from management and partners, especially in the early stages of the project
   e. Management plan for the project and species

5. Monitoring and evaluation
   a. Mark or tag individuals for release
   b. Conduct stock assessment prior to release (baseline information)
   c. Monitor changes in density and size relative to baseline information
   d. Evaluate increase in total catch of the species through time

6. Legal and policy framework
   a. Consider local, national, international laws and policies regarding introduction of species to local waters.

Acknowledgment

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Status and Prospects of Aquaculture of Threatened Echinoderms in the Philippines for Stock Enhancement and Restocking

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Echinoderm Values

Two echinoderm groups have significant fisheries in the Philippines: sea cucumbers and sea urchins. For sea urchins, the gonad or roe is the valuable product while the dried body wall of sea cucumbers called *trepang* or *beche de mer* is sought in the world market. Unlike sea urchins which are traditionally consumed throughout the Philippines, sea cucumbers are not as popular except in Chinese specialty restaurants. However, there are anecdotal accounts of small holothurian species eaten fresh in central and southern Philippines. Trepang is preferentially exported to Asian markets, primarily Hongkong.

Like the sea urchins, trepang from sea cucumbers can fetch high prices in the world market depending on species and size. The sandfish *Holothuria scabra* sells at US$45-50/kg (Anon. 2002) and is a major species targetted by fishers/gleaners. Reportedly with tonic properties that range from aphrodisiac to cure for osteoarthritis, trepang is called the sea ginseng, a cure all for ailments (Chen 2004).

The economic value of the ecological roles of commercially important echinoderms still remains to be priced. But the herbivorous sea urchins promote higher ecosystem primary productivity in coral reefs and seagrass beds, and facilitate energy flow to higher trophic levels. Their intense herbivory can lead to predominance of well protected sessile organisms particularly those with calcareous skeletons (Wood 1999). Detritus-feeding sea cucumbers are important bioturbating agents that rework and aerate sediments as well as recycle minerals and nutrients. Their presence and biological activity have been demonstrated to improve sediment quality by decreasing organic matter deposition and inhibiting harmful algal bloom (Michio et al 2003). The various life stages also form important food web components both in the plankton and benthos of the sea.

Echinoderms are either specifically targeted by gleaners and divers, or form part of the multispecies invertebrate fishery in many coastal areas in the Philippines. The existence of a local sea urchin market in northern Philippines (e.g., Pangasinan, La Union) benefits many coastal families that depend on this fishery for subsistence. In Bolinao, Pangasinan, over 40 families are reportedly dependent on this fishery. Major sea urchin species collected include *Tripneustes gratilla, Diadema* spp. and *Salmacis* spp. In the case of holothurian fishery, with over a century of fishery history for holothurians, at least 25 species mostly belonging to the families Holothuriidae and Stichopodidae are commercially important (Schoppe 2000). While there may be local consumption of both fresh and dried products, the latter are largely exported.

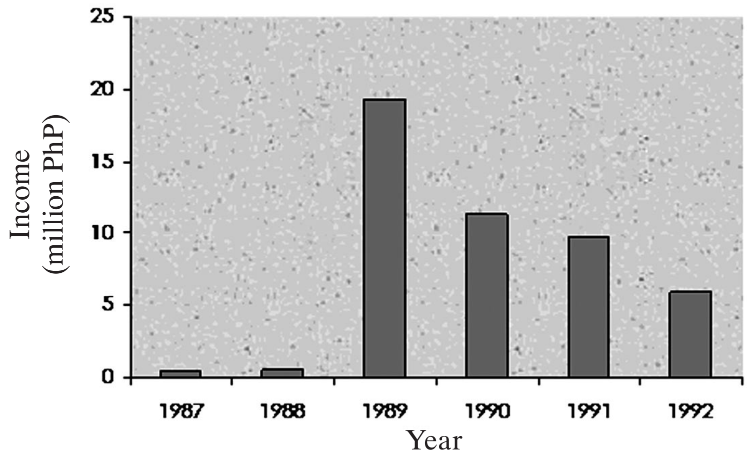

Fig. 1. Annual income from sea urchin fishery in Bolinao, Pangasinan: 1987-1992.

Echinoderm fishery is dependent on wild stock. The high demand far exceeding supply, good global market prices and their biology (e.g., slow mobility, shallow water benthic habitat) render them vulnerable to overexploitation. So tales of local fishery collapse, e.g., that of *T. gratilla* in Bolinao, Pangasinan in the early 1990s (Juinio-Menez 2004), or accounts of local depletion of sea cucumber populations in many areas are not at all surprising. The erratic values of trepang production in the Philippines amidst an overall decreasing mean volume in the last decade (Akamine 2003, Gamboa et al 2004) further show how fragile and unsustainable the fishery has become.

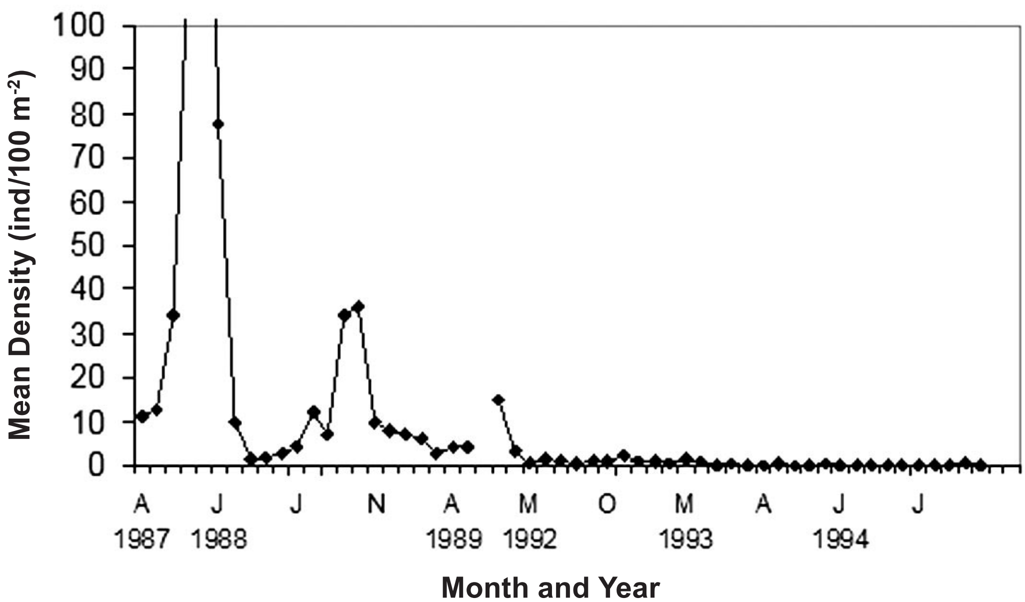

Fig. 2. Mean density of natural *Tripneustes gratilla* populations in Bolinao, Pangasinan: 1987-1994.

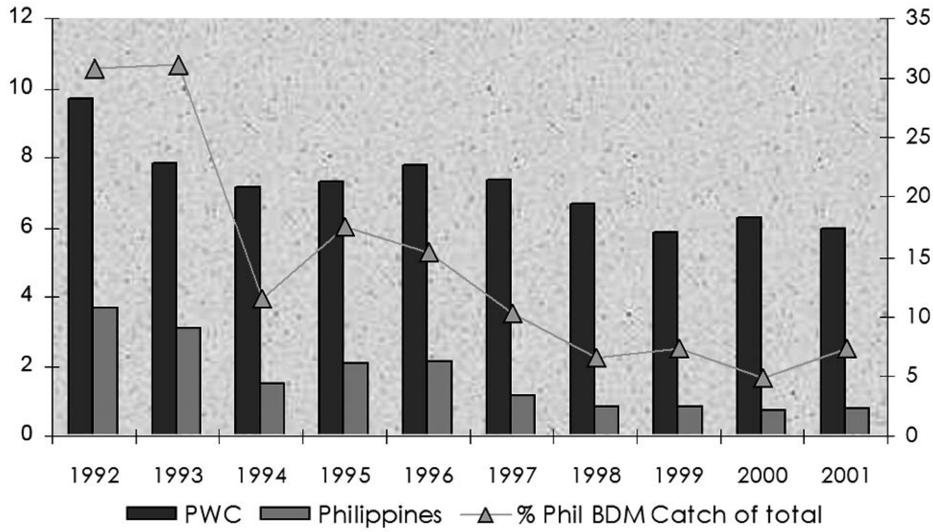

Fig. 3. Production of *beche de mer* from the Philippines and West Central Pacific: 1992-2001 (from Conand 2004).

The contribution of echinoderm products to the Philippine economy is substantial. Reported income from sea urchin fishery in Bolinao, Pangasinan alone at the peak of its fishery in 1989 was estimated at nearly PhP20 million but declined to PhP5 million in 3 years as natural populations collapsed (Figs. 1 and 2).

National sea urchin fishery production estimated at 1,100 mt fresh weight in 1992 declined to only about 380 mt in 1998. At current prices of PhP80-150/kg, the 1998 production should have a value of PhP3-5.7 million generated in Bolinao, Panagasinan alone. The collapse of sea urchin fisheries due to overexploitation (e.g., the Bolinao case) has resulted in the loss of millions of pesos representing the livelihood of numerous coastal families.

In the case of sea cucumber fishery, the Philippines was the second largest producer in the early 1990s (Conand 2004). However, beche de mer production and the country's market share relative to the Pacific West Central total production showed general declining trend from 30% to 5% within the last decade (Fig. 3). About US$6 million (~PhP300 million at US$1= PhP50) was generated in 2000 from *beche de mer* trading (Akamine 2003).

The relative contribution of echinoderm products to the income and socio-economic well-being of fisherfolk who collect these invertebrates is undocumented. However, it has been noted that middlemen, especially local buyers who sell trepang in Manila and Manila-based traders-exporters monopolize the profits (F. Nievales, unpublished data).

Products from both echinoderm groups remain in short supply in the country and so trading, limited only by declining natural stock, continues to be lucrative.

Initiatives in Echinoderm Culture

Initiatives to develop the culture technology for important echinoderms arose from the need to develop alternative management schemes to sustain their fishery and to increase the number of cultivable species for mariculture.

The need for echinoderm culture and resource management to sustain a thriving fishery was probably sounded off as early as the 1980s (e.g. Roa-Trinidad 1987). Studies on reproductive biology and attempts to culture echinoderms gained momentum only in the mid-1990s for sea urchin and 2001 for sea cucumber. Earlier studies on reproduction and culture focused on the sea urchin *T. gratilla* (Tuason and Gomez 1978, Formacion 1985, Dabandan 1987) and sea cucumber *H. scabra* (Ong Che and Gomez 1985, Seraspe et al 1985), *Bohadschia marmorata* and *Actinopyga echinite*s (Seraspe et al 1985, Seraspe et al 1987, Nievales and Rocio 1989, Seraspe et al 1994).

Serious attempts to develop echinoderm hatchery and grow–out culture in the Philippines were undertaken at the outdoor hatchery facility and marine laboratory of the University of the Philippines Marine Science Institute (UP-MSI) in Bolinao, Pangasinan. Culture began in the mid-1990s for the sea urchin *T. gratilla,* and in 2001 for the sea cucumber *H. scabra*. To date, UP-MSI remains at the forefront of echinoderm culture and extends financial support and resources to interested scientists and students.

Pilot scale hatchery production of juveniles for stock enhancement and mariculture was implemented for *T. gratilla* and *H. scabra* with financial support mostly from the national government (e.g., Department of Agriculture). Efforts to refine culture protocols for stock improvement and seed stock production have been funded by foreign sources, e.g., the Coastal Resource Management (CRM) Project supported by the Netherlands Embassy in 2002.

Choice of echinoderm species for culture

A number of attributes make the two species (*T. gratilla* and *H. scabra*) important candidates for stock enhancement, restocking, sea ranching and mariculture in the Philippines. Firstly, these are threatened species with high market value, large and undersupplied demand in the world market, and a fishery dependent solely on wild stocks. Indeed, both species continue to face unsustainable fishery problems that often result in local depletion (e.g., 1992 collapse of sea urchin populations in Bolinao). Second, these species are amenable to culture (e.g., with continuous breeding pattern), relatively well studied, and with existing technology in and outside the Philippines that can be adapted to local conditions. Thirdly, local grow–out protocols are environment-friendly with no high–protein formulated inputs that other aquaculture species need. Because it is extractive aquaculture, raising sea cucumbers in deteriorating habitats could improve sediment quality. The prospective return on investment for grow-out culture of these two species is promising.

Table 1. Duration of different life stages of echinoderms based on culture.

Phase	***Tripneustes gratilla***	***Holuthuria scabra***
Planktonic	42-52 days	12-21 days
Duration to visible juveniles	1 mo (1 cm test diameter)	1 mo (1 mm length)
Duration to size at release/grow out	1 mo (3 cm test diameter)	1-2 mo (4-8 g)

Table 2. Growth in size (body weight in g) and survival of juvenile *Tripneustes gratilla* in field cages with different conditioning histories after varying periods (in days).

Conditioning history	after 10 d	after 19 d	after 30 d	after 60 d	Survival after 60 d (%)
Without sand	4.15	6.55	6.38	6.77	83
With sand	6.28	7.58	7.64	7.28	100

Status of local culture technology

Tripneustes gratilla and *H. scabra* are both dioecious (i.e., with separate sexes), continuously breeding and spawn their gametes in the water where fertilization takes place. Development is indirect and hatched embryos pass through a dispersive larval stage (echinopluteus for *T. gratilla* and auricularia for *H. scabra*) and later metamorphose and settle. The life cycle is thus complex involving benthic and planktonic phases. Table 1 shows the duration of different life stages under hatchery conditions of these two species prior to grow-out — hatchery and land-based nursery periods require 3-4 mo before seeds are available for grow out culture.

Tripneustes gratilla

Local culture technology for *T. gratilla* is well established with high survival during larval period at presettlement (87-96.5 %). Survival to early juveniles (>1.0 cm test diameter) is 13-30.5%. Thus, annual production of 80,000 seeds for reseeding or grow-out is now attainable at the UP-MSI Bolinao outdoor facility.

Pilot grow-out culture in cages by fishers is promising. Growth rate to marketable size of sea urchins in sea cages is high with minimal mortality. Gonad quality and yield which are important traits for the export market are good. A manual for sea urchin grow-out culture is already available (Juinio-Menez et al 2001).

Holothuria scabra

Cost-effective hatchery and growout culture technology for *H. scabra* is continually refined and developed at the UP-MSI Bolinao hatchery facility. Methods for larval rearing, settlement and juvenile rearing of *H. scabra* developed in India (James et al 1994), Solomon Islands (Battaglene 1999a, Battaglene et al 1999, Battaglene et al 2002, Pitt, 2001) and Vietnam (Pitt and Duy 2003) are adopted and modified.

Larval survival can be high (60% to over 90%) prior to settlement. Best results for post-metamorphic survival until juveniles start to be visible (~1 mm length) is 33% (mean ~10%) in small-scale rearing vessels (3 L jars). However, remaining inter-batch variability in juvenile survival needs to be resolved.

From visible size, juveniles reared in settlement tanks/jars are transferred to nursery tanks. These are periodically graded according to size until they reach over 10 mm length when they can be transferred to tanks with sand. Preliminary studies suggest that juveniles grown in tanks with sandy substrate exhibit better growth in the hatchery (Fig. 4) and when transferred to sea cages (Table 2) than those without sand. Survival in cages was also higher for juveniles with prior sand conditioning in the hatchery than those without.

Studies continue on reducing the land-based nursery period as a strategy to cut costs in rearing sea cucumber juveniles. With

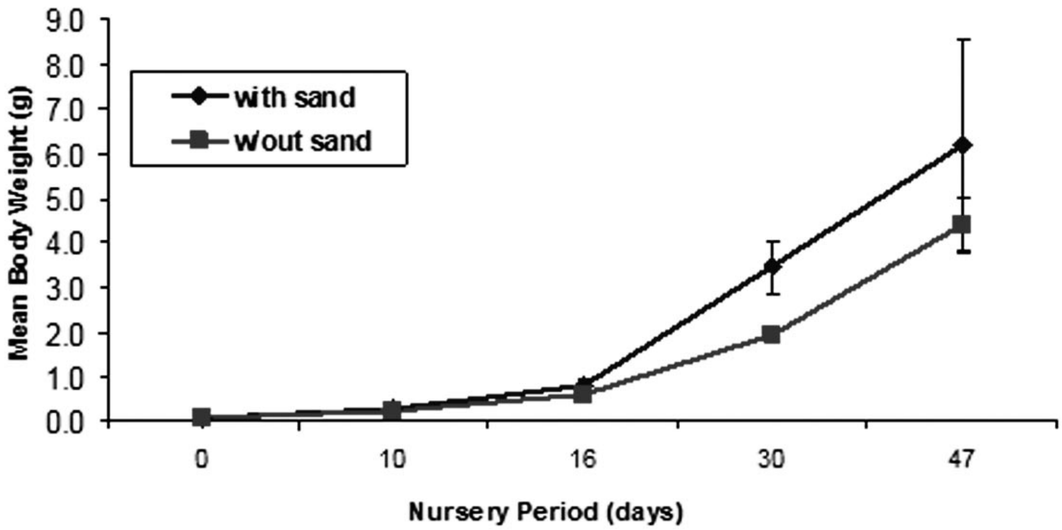

Fig. 4. Body weight (g) of juvenile *Holothuria scabra* in aquaria with and without sandy substrate.

programmed induced spawning and larval production, a target of 10,000 juveniles for reseeding and grow-out is feasible at the UP-MSI Bolinao outdoor facility.

Ongoing field studies continue to show that juvenile survival is not compromised if they are first transferred at >1 g sizes to predator-proof cages in the field for growing to sizes suitable for transfer to bigger pens or for release in the wild.

Stock Enhancement Activities

Reseeding of *T. gratilla* concentrated in Bolinao, Pangasinan and other municipalities in Lingayen Gulf has been more or less continuous since the mid-1990s. Community-based grow-out of hatchery juveniles has been sustained in some sites, providing supplementary livelihood to local people. In the last 2-3 years alone, more than 10,000 juveniles were given to various people's organization (PO) partners through the UP-MSI CRM project funded by the Netherlands Embassy. Several thousands have also been reseeded in sanctuaries including the Hundred Islands Marine National Park in Pangasinan.

Over 50,000 *H. scabra* juveniles have been produced since 2001. A few thousands have been reseeded in a marine sanctuary in the Lingayen Gulf. In 2005, experimental grow-out of hatchery juveniles was initiated in three partner municipalities of the Dutch-funded CRM project. Preliminary results show that while growth rate of juveniles in pens is high, choice of site is a critical factor in survival.

Future Directions

Hatchery technology and grow-out culture for *T. gratilla* are well worked out, but post-metamorphic survival can be improved through more effective metamorphic cues. There is also need to focus on product development by aiming for high value sea urchin products.

Local protocols in sea cucumber culture need more fine tuning to improve post-metamorphic survival (through effective metamorphic and settlement cues and preventive measures against diseases of early juveniles), and to determine optimum size and strategy for field deployment of hatchery produced juveniles.

Grow-out culture, reseeding of juveniles and broodstock maintenance in sea cages within protected areas are viable resource management tools for repopulating depleted sea urchin populations and providing supplemental livelihood to fishers. The presence of natural recruits and existence of a small scale fishery indicate stock recovery in Bolinao a few years after these interventions were introduced (Juinio-Menez 2002 in Juinio-Menez 2004). Ongoing population monitoring of *T. gratilla* in Bolinao sites shows improved densities of 10-65/100 m^2 compared to zero density when the fishery collapsed 10 years back.

There are plans for a national research program on holothurians to include an inventory of economically important sea cucumbers in the country and to establish seed centers for future stock enhancement and mariculture activities. Partnership with the private sector in echinoderm research and development will help scale up seedstock production and optimize the economic potentials for small and industrial scale culture. Along this line, development of multi-species invertebrate hatcheries will expand options for sustainable mariculture and benefit a broad spectrum of fishers, aquaculturists, traders, food processors, and entrepreneurs.

Nevertheless, restocking and stock enhancement and even sea ranching/farming of echinoderm juveniles from hatcheries should not be viewed as a single panacea for seriously threatened populations. Indeed, reproductive reserves from hatchery produced juveniles, together with reseeding, helped the recovery of natural stocks of *T. gratilla* as recent studies show. However, some aspects of intensive culture such as reduction in genetic diversity and diseases must be carefully considered when promoting culture-based fishery.

A holistic and integrated approach is important in fishery management of threatened echinoderm resources. Setting sustainable catch levels and monitoring impacts of stock enhancement require benchmark ecological information. The same is required in deciding whether stock enhancement or restocking activities are necessary options. In most cases, basic stock inventory of fishery resources is conducted only after serious depletion has taken place. Moreover, there are practically no fishery management regulations for invertebrates in the country. Capital investment for, and maintenance of, an echinoderm hatchery facility can be sizeable and the problems of growing and releasing hatchery juveniles remain.

The Philippine Constitution and fishery laws safeguard the overexploitation of marine resources, including these invertebrate groups. However, a basic understanding of the biology and life history of fishery resources and important ecological concepts (e.g., connectivity, viable population size, Allee effect on reproduction, trophic dynamics) is very limited at the grassroots. These concepts have to be continuously inculcated in national and local government officials and key stakeholders responsible for implementing the national Fisheries Code. The country needs sustained advocacy and incentives for responsible and ecologically sound fishery (i.e., both capture and culture) practices. Aside from effort regulation, appropriate management interventions such as the establishment of marine protected zones or sanctuaries should remain an important part of an integrated fishery resource management scheme.

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An Uncertain Future for Seahorse Aquaculture in Conservation and Economic Contexts

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Introduction

Once fisheries are overexploited, conservation and fisheries communities have a shared goal and a common commitment to adjust extraction to sustainable levels. To persist with overfishing is both biologically irresponsible and disrespectful of the long-term needs of dependent communities. Measures must, therefore, be put in place that will adjust fishing to meet regional or national intergenerational responsibilities to marine life and people alike. Ventures such as aquaculture and marine protected areas may help to move levels of extraction towards sustainability, but there are no substitutes for integrated management and reductions or alterations in effort.

Fisheries managers may not realize the potential of the conservation agencies to help with such adjustments of exploitation. The IUCN (World Conservation Union) Red List (www.redlist.org) and CITES (Convention in International Trade of Endangered Species of Wild Fauna and Flora, www.cites.org) Appendix listings are two among many conservation tools available to every country in its pursuit of sustainable fisheries. They are, however, so misunderstood that both tools are commonly miscast as the enemy of exploitation. In fact, the IUCN Red List serves as an important warning mechanism that a species (or sometimes a population) may be in trouble. It has no legal power or restrictions, unless local jurisdictions choose to confer such authority. Moreover, current listing approaches have been recast to recognize that some numeric depletion is a reality in active fisheries, while insisting that such changes must be understood (www.redlist.org/info/categories_criteria2001.html). It is important to note that most listings are completed on a global basis and may not reflect regional or national situations, each of which requires separate assessment.

Any restrictions by CITES (itself an agreement among 169 signatory nations) will be implemented at the national level, according to local conditions. A species may be placed on Appendix I, which essentially bans international trade. Far more commonly, however, CITES places species on Appendix II, a list denoting anxiety about the potential threats caused by unmanaged trade, and requiring regulation of exports. It is important to note that each individual CITES signatory nation determines how best to manage its exports so as to ensure they meet the CITES requirements. These, simply, are that exports must not be detrimental to wild populations and that exports must be legally obtained (and that live animals must be properly transported). Such requirements should provide welcome assistance to fisheries managers faced with overexploitation or illegal fishing. Moreover, CITES can sometimes add particular value to international fisheries management in at least three situations: (1) where other regional or international plans are weak, unimplemented or absent; (2) where species are of such limited commercial value that they will not be of interest to other conventions or agreements; or (3) where CITES includes fishing nations not associated with another convention that seeks to regulate extraction of species they exploit.

Given that each national government chooses how to respond to both IUCN Red Listings and CITES, domestic assessments of species of concern are terribly important to any conservation process. For any given country, the species of concern may or may not be those judged in need of support at a global level. A species considered to be globally healthy may be of conservation concern domestically, but equally a species of global conservation concern may be healthy domestically. Countries are thus faced with the challenge of determining where best to direct their own energies, with national assessments of decline and degradation. Moreover, they are charged with identifying relevant management measures.

Culturing and releases are often mooted as conservation responses that should also enhance production. Yet any such initiatives can encounter or provoke enormous ecological, economic, and social problems. It is very rare for aquaculture or releases to resolve conservation problems, even partly. It is almost impossible for them to do so unless the pressures that led to depletions have been relieved. Thereafter, it is always vital to understand the species and its status, identify a clear management goal and objectives, plan and execute the initiatives with great care, and measure the outcomes and impacts of the venture. Moreover, it is important to comply with guidance and regulations from such bodies as the Convention on Biological Diversity (CBD: www.biodiv.org) and the IUCN Reintroduction Specialist Group (RSG: www.iucnsscrsg.org). Failures in these respects can lead to intemperate action that is often considerably worse than no action at all.

Seahorses (family Syngnathidae, genus *Hippocampus*) have set precedents globally. They were among the first marine fishes of commercial importance to be listed on both the IUCN Red List and CITES Appendix II. Overfishing and non-selective fishing are two agents in their depletion, so management is clearly needed. We here outline what is known about these fishes and their trade, before considering the potential role the culture and release could play in rebuilding wild populations.

Trade and Conservation Status

Seahorses are found primarily in temperate seagrasses and tropical coral reefs, but also occur in mangroves and estuaries. At least 27 species occur in the IndoPacific, with new species still being proposed (Lourie et al 2004, http://seahorse.fisheries.ubc.ca/IDguide.html); adults of the different species range in maximum adult height from 2 to 28 mm. A recent review summarized extant knowledge on seahorse biology and ecology (Foster and Vincent 2004). They are generally found at low population densities, with occasionally more dense patches; such distributions may represent a combination of natural rarity and considerable depletion. These fish live about 1-5 years. Their diet of live prey apparently changes as they grow, but such relationships are poorly understood, especially when compared to their reproductive biology. Relative to their maximum size, seahorses first mature at much the size we would expect from relationships in other teleosts. All seahorse species are thought to be monogamous within a reproductive cycle, but some may be polygamous across cycles. Females transfer eggs directly to the male's brood pouch, where they are fertilized, making it difficult to assess clutch size. At the end of their pregnancy, however, males release c. 5-2000 young, depending on species and adult size. Newborn young are born at about 2-20 mm in height, at a size that is not directly related to adult size. Seahorses often maintain small home ranges, and generally swim slowly.

It appears that seahorse populations are commonly vulnerable to overexploitation, whether direct or indirect (Foster and Vincent 2004): low population densities mean that seahorses may have trouble finding a mate; possible low rates of natural mortality mean that heavy fishing will place new pressures on the population; monogamy in most species means that a surviving partner may stop reproducing, at least temporarily; male brooding means that survival of the young in the pouch depends on the survival of the male; a small brood size limits the potential reproductive rate of the pair (although this may be offset by frequent spawning and enhanced juvenile survival through parental care); and low mobility and small home range sizes mean that seahorses may be slow to recolonize overexploited areas (although this may be offset by planktonic dispersal of juveniles). Their social and spatial structure is such that those seahorses returned to the water after being caught in non-selective gear may still be damaged through physical injury, habitat disturbance, disruption of pair bonds, and displacement from home ranges.

Extensive trade surveys have revealed that a great many countries are trading a great many seahorses, with grave consequences (Vincent 1996, McPherson and Vincent 2004, Giles et al 2005, Baum and Vincent 2005, Martin-Smith and Vincent 2006). Traditional medicine (TM) – and particularly traditional Chinese medicine (TCM) and *jamu* from Indonesia – accounts for the largest consumption of seahorses, and they are also fished in substantial numbers for the aquarium and curiosity trades. Published reports have documented large and growing exploitation of seahorses, pipehorses, and pipefishes. At least 32 countries had traded syngnathids by 1995 (Vincent 1996), but this had increased to nearly 80 countries by 2001, with much of the expansion in Africa and Latin America (McPherson and Vincent 2004, Baum and Vincent 2005). Trade in Asia alone was inferred to amount to more than 45 metric tonnes (mt) of dried seahorses in 1995 (Vincent 1996), with much expansion thereafter. Seahorses in trade weigh a mean of perhaps 2.9 g, with great variation by country, region, species, and individual, hence the 1995 volume in Asia may have represented c. 15.5 million individuals.

Direct exploitation, incidental catch in non-selective fishing gear, and habitat loss and degradation (much of it fisheries-associated) have put considerable pressure on seahorse populations in many regions. Fishers and other informants reported substantial numeric declines in seahorse catches and trade, without commensurate decreases in effort (e.g., Giles et al 2005, Baum and Vincent 2005). Estimated population declines of between 15 and 50% over five-year periods have been common, with marked declines in size of landed adult seahorses (Vincent 1996). All known species of seahorses appear on the IUCN Red List of Threatened Species as Endangered, Vulnerable or Data Deficient (www.redlist.org).

CITES regulates the international trade in seahorses, as an important component of collaborative efforts to achieve sustainable use of these fishes. All seahorses were listed in Appendix II in 2002 (www.cites.org), with the regulations taking effect in May 2004. Seahorses are among the first marine fish species of commercial importance to be listed on the Convention, and represent a particularly large wildlife trade issue, by volume of animals exported each year. The CITES Animal Committee recommended that Parties seeking guidance in implementing the Appendix II listing for seahorses consider adopting a 10 cm minimum size limit, as one means of moving towards sustainable trade (Foster and Vincent 2005). Other measures will also be necessary for a successful seahorse conservation strategy.

CITES recognizes the potential role of aquaculture in arriving at sustainable trade. All cultured animals can be traded under

Appendix II. The first generation (F_1) will be treated as wild, with a requirement that exports be guaranteed not to damage wild populations. Subsequent generations (F_2 and above) from operations certified by the national government are exempt from such controls, as long as their paperwork is in order. What, then, is the potential for viable seahorse aquaculture and for benefits from subsequent releases of cultured seahorses?

Aquaculture Status

Seahorses have been cultured since the 1970s, particularly in China, but breeding and rearing seahorses has been problematic (Xu 1985, Vincent and Clifton-Hadley 1989, Dao and Hoang 1991, P ham and Dao 1991, Fenner 1998, Hargrove 1998, Truong 1998, Chaladkid and Hruangoon undated, Hormchong et al undated). The published literature from mainland China conveyed the impression that seahorse culturing was well understood (e.g., Aquaculture Institute of Shanghai 1982, Wu and Gu 1983, Shandong Marine College 1985, Publicity and Education Committee 1990). However, for many years problems with vulnerability to disease and providing the correct diet meant that these facilities were experimental rather than commercially viable. The restructuring of China's economy in the 1980s led to widespread closure of seahorse farms, just at a time when China's demand for seahorses accelerated (Vincent 1996).

Global interest in aquaculture of seahorses and other syngnathids (pipefishes, pipehorses and seadragons) has increased dramatically over the past decade, largely coincident with awareness of the seahorse trades and their associated conservation issues. Research and development into seahorse culture has been carried out by over 40 ventures in at least 20 countries, including the following: Australia, Brazil, China, Ecuador, India, Indonesia, Mexico, New Zealand, Philippines, South Africa, Vietnam, and the USA. Although historically most culture operations were located in China, recent ventures are frequently found in Australia or New Zealand. The potential to culture seahorses in closed systems means they could potentially be cultivated in many countries, but compliance with the precepts of the CBD means that any culturing should occur in range countries using systems that minimise negative environmental impacts and maximise local socioeconomic benefits.

A few recent ventures for seahorse aquaculture have been commercially successful and are working as effective businesses but most are either in the pilot stage or have failed because of commercial or technical problems. The low number of operations in each country and a lack of knowledge transfer among operations mean that the same mistakes are often repeated. Many operations close simply because they relied on overly optimistic business models, with heavy dependence on subsidies that are only available in the pilot phase and with inadequate market research. Others are still battling technical challenges – including provision of the correct diet and vulnerability to disease – and difficulties with commercial suitability. No standardized method for culturing seahorses has yet emerged, and systems vary according to location and intended market.

Seahorses are currently being cultured to supply TM and tonic products (e.g., seahorse wine), live aquarium fishes, and curios and souvenirs. The scale of seahorse culture facilities ranges from small aquariums to large pond systems and from research-based to commercial operations.

1) No culture operation that targets the TM market appears to have achieved commercial viability. Even the largest seahorse farm in China is still at the developmental stage and has not reached full commercial production. Moreover, this operation is promoting the development of new domestic markets for its products, with a particular

focus on its own brands of seahorse wine, capsules, and concentrate for TCM. Should the operation fail, such newly generated demand could add to pressures on wild populations.

2) At least five companies now supply cultured seahorses to the aquarium trade, relying on low volumes and high values: two in Australia, one in Ireland, one in Sri Lanka, and one in the USA (Hawaii). The level of production varies enormously among companies, with some of these still at the development stage. The few quoted prices on websites are US$75-370 per individual or pair, with some companies selling seahorses as part of a 'kit', along with their food. Cultured seahorses that eat frozen food are more adaptable to a home aquarium environment than wild-caught seahorses. The ratio of wild-caught to cultured seahorses in the live aquarium trade is unknown.

3) Seahorse culture facilities are diversifying. One company in Australia now sells seahorses that have died during the culture process as jewellery and marine art, with prices of approximately US$50-100. Another also serves as a tourist attraction, reporting nearly 17,000 visitors in 2004.

Both tropical and temperate seahorses are being cultured. The tropical species include *H. barbouri, H. erectus, H. fisheri, H. fuscus, H. histrix, H. ingens, H. kuda, H. mohneki, H. reidi,* and *H. trimaculatus.* Temperate species include *H. abdominalis*, *H. breviceps, H. capensis, H. whitei,* and *H. zosterae*. Most have been located in Australia and New Zealand, with a focus on *H. abdominalis*, but some ventures are also starting to culture the temperate European species, *H. guttulatus* and *H. hippocampus.* Attempts to culture *H. abdominalis* for the TM market failed because of a lack of market research and other challenges. The TM market has very specific requirements with respect to shape and spininess rather than selecting by species. Given that most marine aquaria are tropical, the market for temperate species will always be more limited than that for tropical species.

The last five to ten years have seen advances in the culture of seahorses, with the closure of life cycles over a number of generations for several species (Wilson and Vincent 1998, Payne and Rippingale 2000, Woods 2000a, b, Bull 2002, Job et al 2002) but many technical challenges remain around behavior, disease, and nutrition. The significant social and spatial structure shown by seahorses is unusual for cultured fish and needs to be considered in the facility design and species' management. As well, seahorses are vulnerable to diseases, to the extent that this is one of the constraints for commercially viable aquaculture. Laboratory and aquaculture observations have documented health problems related to bacteria (*H. kuda*: Alcaide et al 2001, Greenwell 2002), cestodes (*H. abdominalis*: Lovett 1969), micro sporidians (*H. erectus*: Blasiola 1979, Vincent and Clifton-Hadley 1989), fungi (*H. erectus*: Blazer and Wolke 1979), ciliates (*H. erectus*: Cheung et al 1980, *H. trimaculatus*: Meng and Yu 1985), trematodes (*H. trimaculatus*: Shen 1982), and marine leeches (*H. kuda*: DeSilva and Fernando 1965).

Feeding and nutrition, especially for juveniles during the first few weeks after release from the pouch, appear to be a major challenge in seahorse cultures, primarily because these fish are obligate predators. The relatively large size of seahorse juveniles (compared to other marine fish) should make them easier to rear but their ontogenetic changes in diet make it necessary to prepare a chain of live food. In general, newly released juveniles are fed 2-7 times a day with some combination of (a) newly hatched *Artemia*, (b) 24-48 h enriched and decapsulated *Artemia* nauplii, (c) rotifers (e.g., *Brachionus plicatilis*), (d) haparcticoid copepods (e.g., *Euterpina acutifrons*), and/or

(e) mysid larvae (e.g., *Mysidopsis bahia*). Adding a small amount of chopped frozen *Mysis* shrimp to nursery tanks immediately after birth may promote feeding and improve survivorship in the fry (Koldewey 2005). The gradual transfer from one live food organism to another is achieved by overlapping different feeds at the different weaning stages. At 7 days, juvenile seahorses are able to take copepods (Wilson and Vincent 1998) and juveniles of 3-8 weeks can be trained to take frozen mysids, with the transition from live to frozen food sources usually taking about a month (Koldewey 2005).

Sourcing live food for seahorses could potentially cause local prey depletion or other negative environmental impacts, unless care is taken. Depending on the location and type of culture facility, adult seahorses are fed live foods, a combination of live and frozen foods, or entirely on frozen foods. Adults are commonly fed 2-4 times daily with live *Artemia* shrimp, *Mysis* shrimp, grass shrimp, copepods, *Gammarus*, poecilid fry, and caprellid amphipods, or with frozen mysids (e.g., *Euphausia pacifica*) and adult *Artemia*. A frozen food diet is the best choice where live foods are only seasonally available or where the seahorses are destined for the live aquarium trade, as hobbyists may have only limited access to live food.

Both juveniles and adults benefit from enriched food, especially if several enrichment products are combined. The many possibilities for enrichment include phytoplankton (e.g., *Nannochloropsis aculata, Isochrysis galbana, Tetraselmis chuii, T. suecica*), essential vitamins, commercial products of (Ω3) highly unsaturated fatty acids such as Selco, Culture HUFA, Roti-Rich, astaxanthene biological pigment Natu-Rose, AlgaMac 2000, amino acid or liquid multi-vitamins, MicroMac 70, Aminoplex, Cyclop-eze, or Beta Meal. Low cost supplements may also be locally available as an effective enrichment for seahorses (Job et al 2002). Some culture facilities offer proprietary diets for seahorses when they sell the animals.

In the context of international trade, facilities face a further challenge in finding a way to distinguish F_2 cultured animals from wild-caught or F_1 seahorses. CITES Authorities require proof that the animals are cultured (from at least F_2 generation) before they can waive export controls. Paper trails can sometimes serve to confirm that seahorses are from cultured rather than wild sources, but physical distinctions are also needed. One operation in Sri Lanka proves the captive provenance of its seahorses by culturing only an exotic seahorse species not found in Sri Lanka (*H. reidi*) but this approach can carry a serious risk of escape or release, with consequent threats to native fauna, and is often banned under national legislation (as well as running contrary to the CBD). In general, however, research is needed to supplement current technical approaches for marking and tagging sea-horses (Morgan and Martin-Smith 2004, Woods and Martin-Smith 2004). For culturing facilities, in particular, such techniques will need to be cheap, easy to apply and to recognize, and free of traits that might compromise sale or use. Good marking and tagging methods are also indispensable for release programs, in order to monitor the released animals and establish the impact, successful or otherwise, of such stocking practices.

Export of live seahorses also poses some challenges. CITES meets the worldwide transport standards defined in the IATA Live Animal Regulations, governing transport by commercial airlines. In consultation with CITES and the Marine Aquarium Council (www.aquariumcouncil.org), specific guidelines have been developed for the transport of seahorses (Koldewey 2005).

Impact of Aquaculture

Seahorse aquaculture could theoretically serve as a rewarding commercial enterprise and as a tool in the conservation of wild populations, but the real conservation benefits of culturing seahorses are still very unclear. Any aquaculture activity that removes animals from the sea, either as broodstock or for fish food, and discharges effluent into the sea will have an impact on the marine environment. Aquaculture has had numerous well-documented detrimental effects on the environment over the past few decades (e.g., Chua et al 1989, Páez-Osuna 2001, Grosholz 2002, Utter and Epifanio 2002). A reputable company will seek certification for its aquaculture operations, through its national government (where such regulations exist) and/or through impending standards from the Marine Aquarium Council (in the case of live trade).

In order to preclude waste of seahorse animals used as broodstock and risk to the marine environment, syngnathid culturing must first be economically viable. This will only happen when sufficiently large numbers of young can be reared through to market size in a cost-effective manner. Moreover, the acceptability and price of cultured syngnathids in the appropriate marketplace need to be ascertained beforehand. Given the economic uncertainties in syngnathid culturing, small-scale studies using minimal numbers of animals should be carried out prior to the initiation of any large-scale culturing efforts, in order to ensure the following:

1) The reproductive biology of the particular species has been thoroughly investigated;
2) Reliable breeding and culturing techniques have been developed;
3) The operation can repeatedly rear a sufficiently high percentage of young to market size at viable cost;
4) Cultured syngnathids will be acceptable in the trade at economically viable prices.

If the culture operation is to avoid adding to conservation concern, it must assess potential damage to the marine environment and implement mitigation programs before seahorse culturing is initiated. Any activity that further degrades the marine environment is unlikely to be in the interest of wild seahorse populations. Seahorse aquaculture ventures need to demonstrate the following:

Source populations are sufficiently well-understood that broodstock can be removed without damaging them;

a) The culturing operation will only remove the minimum number of wild animals required to maintain the long-term genetic health of its captive-bred broodstock;

b) Any long-term capture of wild food for the syngnathids does not negatively affect the local marine ecosystem;

a) Effluent discharged from the facility will not be detrimental to the local marine environment;

b) The risk of escape of captive-bred syngnathids into the marine ecosystem, where they could cause disease and behavioural and genetic problems, is minimised.

No comprehensive environmental impact assessments have yet been undertaken prior to the establishment of a seahorse aquaculture venture. A few culture operations have, however, adopted a responsible approach to seahorse farming, by regulating water discharges, sale of exotic species, and broodstock collection.

Seahorse aquaculture ventures need to recognise the special responsibilities inherent in working with threatened species. Culturing will only be of conservation benefit if it reduces pressures of exploitation on wild populations. A great deal depends on how the dynamics of trade affect the fishing communities in source countries that would otherwise catch seahorses. Conventional business strategies such as price competition and the development of new markets need to be tempered by a clear understanding of the local and global impacts of such strategies on wild seahorse populations.

At its best, aquaculture can potentially simultaneously decrease demand for wild-caught fish and provide sustainable income. At its worst, it either (a) fosters new demand for the species, including wild seahorses, (b) leads to drops in price, forcing fishers to catch more wild seahorses in order to meet their basic needs, and/or (c) displaces fishers onto other vulnerable resources, with consequent economic change without conservation gain. Aquaculture is likely to be of greatest conservation value where it facilitates new alternative livelihoods for seahorse fishers, thereby directly reducing pressure on wild seahorse populations. In the case of seahorses, however, technical complications mean that centralised facilities may be needed to hold broodstock and culture juvenile seahorses through the challenging early weeks before they might be dispersed to fishers for grow out.

Any culturing of seahorse species in non-source countries should actively seek to ensure that fishing communities within the source countries benefit equitably from these endeavours. Indeed, a key requirement of the CBD is the fair and equitable sharing of benefits derived from the exploitation of genetic (biological) resources between countries that commercialize these resources (generally developed countries) and the source countries (generally developing countries). Unless fishing communities derive equitable benefit from their biological resources (e.g., seahorses), there will be no reason for them to protect and manage these resources in a sustainable manner. The result may be an increase in environmentally destructive activities such as coral mining and mangrove clearance. While contributions to seahorse conservation may take many forms, the equitable sharing of benefits with source communities is important in any conservation-oriented aquaculture venture.

Current Status of Seahorse "Stock Enhancement"

The release of captive-bred or captive-held animals is often viewed as a useful method of bolstering threatened wild populations. The prospect of captive breeding for release into the wild is also sometimes used as justification for holding animals in captive populations, a means of disposing of unwanted or surplus stock, or a public relations gesture to attract support for an enterprise. All such releases must be viewed with caution and, sometimes, cynicism. No release should be attempted without guaranteed long-term financial, political, and local support.

Any release of captive seahorses needs to be managed carefully, as it has the potential to severely damage wild syngnathid populations and marine ecosystems. Many syngnathid populations are declining relatively rapidly and there may well be specific cases in the future where releases may have to be considered. However, the IUCN RSG guidelines note that formal releases are lengthy, complex, and expensive processes that require preparatory and follow-up activities. An ill-planned or casual release of seahorses could have disastrous impacts on the wild population through, for example, the introduction of disease. Thorough preparatory activities must be conducted before any release is initiated and a long-term monitoring program must be put into place. Moreover, the factors leading to the original decline in the wild population would also need to be addressed, and management plans set in place to avoid a similar extirpation of the introduced population. Casual releases are strongly discouraged.

At present, there are no formal stock enhancement programs for seahorses. There are, however, anecdotal reports of seahorse releases (juveniles and/or adults), purportedly as a conservation action to supplement local populations. An apparently universal lack of monitoring makes it impossible to assess the positive, negative or neutral effects of such releases. More recently, though, a proposed remediation project has sought technical advice from the IUCN RSG, an approach that is strongly recommended. Hopefully, any work that proceeds will include rigorous assessment of its costs and benefits.

The four main types of releases need to be differentiated because they differ in the severity of their impacts (RSG: www.iucnsscrsg.org):

- *Translocation* would be the transfer of wild syngnathids from one site to another where conditions may be different. Translocated syngnathids may be held in captivity for variable periods of time before being released into the new site.
- *Supplementation* would be the release of captive syngnathids into an area where a wild population still exists.
- *Re-introduction* would be the release of captive syngnathids into an area where the local population has been extirpated (gone extinct locally).
- *Introduction* would be the release of non-native (exotic) syngnathids into an area where there has never been a population of that species.

Most seahorse releases in the past have been informal attempts at translocation or supplementation, with all the attendant risks for recipient wild populations. Three main conservation issues may arise from either planned or accidental releases: (1) disease transmission, (2) genetic threats, and (3) community disruptions.

1. Disease transmission

The release of captive animals must be managed carefully to diminish the risk of disease transmission to wild populations. While disease undoubtedly occurs in wild populations, it is unlikely to reach the proportions and severity seen in many culturing facilities where animals are often maintained at unnaturally high densities in artificial conditions. All animals in captivity, unlike those in the wild, may survive for long periods of time because of the absence of predators and use of medications. Most worryingly, disease treatments have the potential to hide the effects of a disease-causing organism without necessarily eradicating it. Thorough screening procedures are, therefore, essential in any program that transfers captive seahorses into the wild.

The risk of disease transmission is increased when non-native seahorses are introduced into an area. Introduced seahorses may bring with them new disease organisms against which local species may have little or no natural resistance. The potential for disease transmission from captive to wild populations has also been highlighted, in the salmon and prawn aquaculture industries in North America, Asia, Europe, and elsewhere (e.g., Krueger and May 1991, Landesman 1994, Roberts and Pearson 2005). Where these impacts have occurred, the effects on wild populations have been severe.

2. Genetic threats

The genetic diversity of wild populations could be threatened when captive-bred animals are released into the wild. Captive-bred animals are usually obtained from a very limited number of parent animals (founders). Their genetic diversity may, therefore, be quite low in comparison to levels in the wild. If large numbers of these animals are released into an area, there is a very real risk that they could swamp the genetic diversity of the recipient wild population, thus lowering its overall genetic diversity in the long term.

A loss of variability is problematic as genetic diversity acts as a safeguard against randomly occurring events such as disease epidemics and environmental changes that may otherwise destroy entire local populations. Without this diversity, populations are far more vulnerable to such events. Risks are exacerbated if the released seahorses are from a captive population that differs genetically from the wild population as this may also lead to fundamental alterations in the genetic structure of the wild population.

The artificial conditions associated with culturing may result in captive-bred fishes having different genetic traits from those in the wild. Thus, the released fishes may be genetically less adapted to conditions in the natural habitat (Cooke et al 2001, Ireland et al 2002). In the simplest case, the released animals die soon after release, with relatively few conservation consequences. If, however, these animals survive to breed with wild conspecifics, unsuitable genetic traits may be passed on to future generations. This could eventually lead to a reduction in the long-term viability of the wild population, as has occurred, for example, in trout (Leary et al 1993, Garcia-Marin et al 1998)

3. Community disruptions

The release of captive seahorses into areas where wild populations of the same species are present brings risks; a sudden influx of new individuals into a small area could result in changes in the social structure of the wild population as a result of increased competition for food, shelter, and mates. Such alterations in social and community structure may have negative effects on the viability of the wild population.

Risk of disruption to marine communities is perhaps most pronounced when exotic species are introduced into an area. Such introductions may disrupt the structure and function of the local ecosystem, and lead to the extirpation (localized extinction) or extinction of native species. In most cases, the introduced species dies shortly after being released because of incompatibility with the new environment.

In numerous well-known cases, an introduced species thrives in new waters (Arthington 1991, Kaufman 1992, Townsend 1996, Mariusz and Krzysztof 2005). The introduction of an exotic seahorse species into the marine environment, therefore, could potentially lead to the establishment of a viable population that may compete with local species for food and habitat. Such a development could have severe detrimental impacts on the local species and community. Numerous examples of problems associated with the introduction of exotics into aquatic systems exist all over the world, particularly in freshwater. Australia, for example, has a list of noxious introduced fishes, such as the ubiquitous tilapia, goldfish, and carp, which are to be destroyed when caught.

Conclusion

Seahorse aquaculture has received widespread attention because of concerns over declines in wild seahorse populations, and recognition of their high economic value and marketability. Many seahorses are threatened species (www.redlist.org) and all are now listed under CITES Appendix II (www.cites.org). Seahorses are among the largest wildlife trade issues by volume under CITES management. Conservation action is clearly needed, both to revive wild populations and to permit continued exploitation. Such actions will need to include reductions in fishing effort, but could also involve aquaculture, were it implemented in an economically sensible and ecologically sensitive manner.

Seahorse aquaculture globally is still at the early stages of development. Most companies operating for more than five years appear to have focused on providing low volume, high value seahorses for the live aquarium trade. While techniques for culture have improved dramatically over the last 5-10 years, very few facilities are currently operating on a commercially viable scale, largely because of continued technical and financial challenges associated with rearing seahorses.

Conservation benefits of seahorse aquaculture have often been highly questionable, despite many claims as to their aims and achievements. Before commercial seahorse culturing can become useful for seahorse conservation, it will need to achieve economic viability, neutralise environmental impacts, and enhance conservation value. Meeting only the former two conditions will result in commercial enterprises that do little to assist global efforts to protect wild seahorses. In contrast, ventures that also address the global conservation impacts of their activities could potentially have significant conservation benefits. In particular, seahorse aquaculture operations need to do the following:

- Avoid promoting (directly or indirectly) new or increased trade in wild seahorses
- Address their impact on subsistence fishers, and thus wild seahorses and other marine life
- Respect international conventions such as the CBD.

It will always be better to increase the viability of wild populations than to bring animals into captivity for rearing and subsequent release. Release of captive seahorses into the wild is an increasingly common activity around the world and is often mistakenly viewed as a valuable contribution to the conservation of wild seahorses. However, releases can potentially severely harm wild populations of seahorses and will seldom be an appropriate management action. Instead, conservation of wild populations primarily requires alleviation of pressures that caused the declines and their associated concerns. Any conservation action requires that goals, objectives, methods, indicators, and targets be clearly defined. On the rare occasion when planning justifies a release, it is essential that a comprehensive monitoring and assessment programme also be implemented to understand the impacts of such action.

Facilities that are engaged in breeding and rearing seahorses are in a strong position to contribute to research needed for conservation action. From a technical aspect, much more information on seahorse diets and diseases is needed, with appropriate public documentation and dissemination of findings. Aquaculture facilities and CITES Authorities alike also require marking techniques that enable the easy identification of cultured seahorses in trade. Furthermore, considerable research is needed on life history parameters that could advance seahorse conservation and management, including (a) fisheries dependent and fisheries-independent abundance estimates, (b) age- or stage-based natural and fishing mortalities, (c) growth rates and age at first maturity, and (d) intrinsic rates of increase and age- or size-specific reproductive output. Such information would contribute greatly to conservation in the wild, which must, after all, be our first priority with any species of concern.

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Status of the Mekong Giant Catfish, *Pangasianodon gigas* Chevey, 1930 Stock Enhancement Program in Thailand

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Introduction

The Mekong giant catfish (*Pangasianodon gigas* Chevey, 1930) is one of the largest freshwater fish in the world, measuring up to 3 m in length and weighing in excess of 300 kg. It is endemic to the Mekong River Basin area. It is found in Tonle Sap Lake, Tonle Sap River, and the Mekong River. It is not known to occur in the upper 2,000 km of the Mekong River. The current extent of occurrence is estimated at around 4,150 km.

Historical reports indicate that the species was abundant in the early 1900s with 40-50 fish caught yearly in Nong Khai Province, north-east Thailand. However, since that time the number of fish caught has declined. In 1967, fishermen captured 11 *P. gigas* in the area (Pookaswan 1969) and by 1970, this fish was caught only as by-catch of beach seine fisheries (Pholprasith and Tavarutmaneegul 1997). From 1980 to the present, it has been found in Chiang Khong District, Chiangrai Province, Northern Thailand. The number of fish caught in Chiang Khong is shown in Fig. 1. The catch has declined from 69 fish in 1990 to just 7 fish in 1997. In 1999, 20 fish were captured in Chiang Khong, but no fish were caught in the area during 2001-2003 which may be due to the blasting of rapids in Chiang Saen District, north of Chiang Khong. Since 1999, the giant catfish has also been reported in the Tonle Sap River, Cambodia.

Rarity and size

The Mekong giant catfish has been listed on CITES Appendix I since 1975 and classified as "Endangered" on the IUCN Red List in 1996. It has been classified as "Critically Endangered" on the IUCN Red List since 2003 after the fish disappeared from Chiang Khong in 2001-2003.

It can be assumed that the Mekong giant catfish is threatened due to human activities, such as overfishing or alterations to the environment (increasing disruption of migration corridors, from construction of dams and weirs means fragmentation of existing habitats etc.). Furthermore, it may be rare because it is evolving or is a relic species of an old group.

Its large body size may also be a reason for its rarity. Data from FAO FishBase showed that the proportion of threatened fishes increases substantially for maximum sizes exceeding 100 cm length, and that most fish species that grow to this size are threatened. In general, large bodied fish tend to be more susceptible to fishing, partly because of their relative mobility, which increases the likelihood of encountering fishing gears. Further, the preference of most fishers for large, valuable fish, and the fishery itself appears as a likely cause of the decline of *P. gigas*. The situation for the Mekong giant catfish is further aggravated because fishers target them in the spawning grounds.

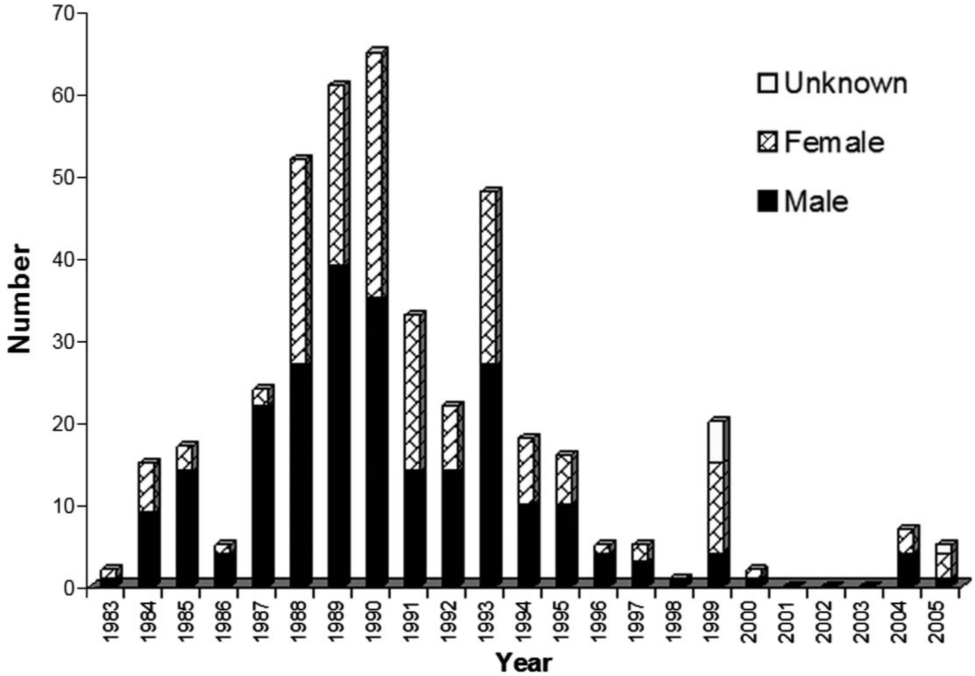

Fig. 1. Number of giant catfish *Pangasianodon gigas* caught in Chiang Khong District, Chiang Rai Province, Thailand, from 1983 to present.

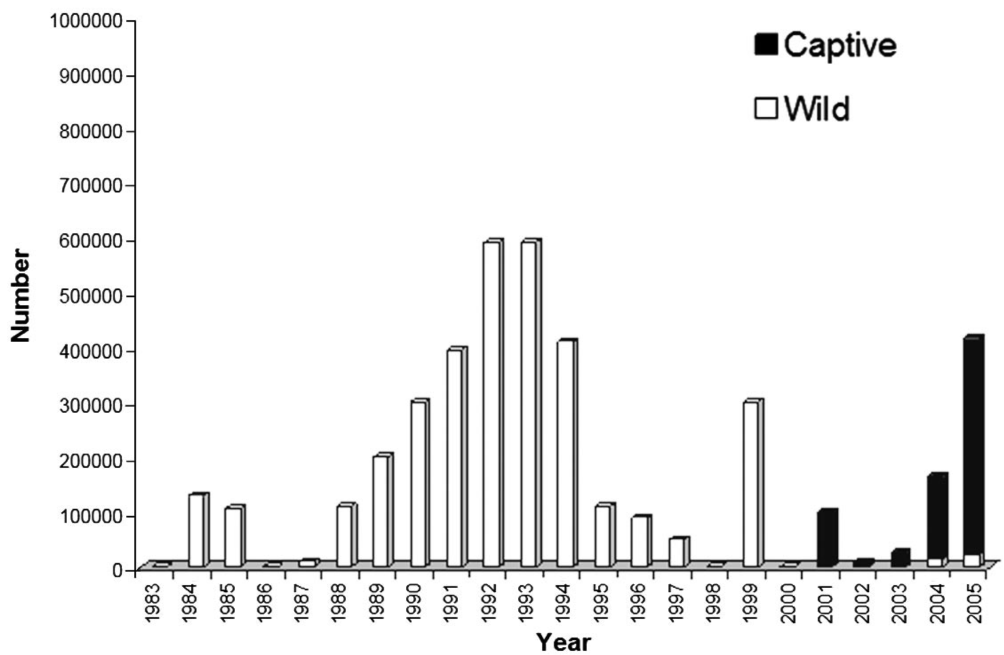

Fig. 2. Number of Mekong giant catfish fingerlings produced from wild sourced and captive broodstock from 1983 to 2005. Since the 2005 spawning season of the captive broodstock has just started, the number of fingerlings reported reflects the partial total production for 2005.

Natural food

After the yolk sac has been absorbed, giant catfish hatchlings are fed zooplankton (*Moina* sp.) for two weeks. The fry are cannibalistic (Pholprasith 1983). When the fish are one year old, they become herbivorous (Pookaswan 1969). Adults feed on filamentous algae, but probably also ingest insect larvae and periphyton. The lack of dentition on the jaws and vomer area has led fishery biologists to believe that the fish feeds on algae growing on submerged rocky substrates (Pholprasith 1983).

Natural spawning season and spawning grounds

The natural spawning season of the Mekong giant catfish is from late April to mid-May but the location of the spawning grounds is poorly known. One well-known spawning site is in the mainstream of the Mekong River northward from Chiang Khong in northern Thailand (Pholprasith and Tavarutmaneegul 1997) where mature fish have been caught annually during the spawning season. Thongsaga and Pholprasith (1991) reported that local fishermen observed mating behavior of *P. gigas* in the Mekong River about 30 km upstream of Chiang Khong.

Age and size at first maturity

There is no report on the age at first maturity in nature. The spawners that were caught in Chiang Khong in 1984-1990 were estimated to be 6-12 years old with body weight of 150-250 kg (Pholprasith and Tavarutmaneegul 1997). Mature females are larger than the males. Captive spawners were 14-18 years old with a body weight of 40-60 kg.

Breeding Program

The Thai Department of Fisheries (DOF) launched a breeding program for wild Mekong giant catfish in 1980 after obtaining fish with mature gonads in Chiang Khong. Present fishing activities in Chiang Khlong cannot be stopped since it is "the way of life" of people as it generates income. The Thai DOF then uses a short period of 2-3 days before the fish are killed, to induce the fish to spawn.

The first successful artificial breeding of wild spawners caught in the Mekong River was reported in 1983. Since then, successful breeding has been achieved every year, except in 1986 and 1998 (Fig. 2). Initially, the hypophysation technique was used. Since 1992, gonadotropin hormone-releasing hormone analogue and dopamine antagonist have been used successfully in induced spawning (Leelapatra et al 2000).

The offspring of the wild-caught parental stock which were reared continuously in captivity for about 17 years were successfully bred for the first time in 2000. Since 2004, broodstock that were reared in closed recirculating cement tank systems have been induced to spawn successfully. It can now be concluded that the life cycle of the captive *P. gigas* stock has been completed by the Thai DOF.

Cryopreservation of sperm

Using cryopreservation, spermatozoa of male Mekong giant catfish were successfully preserved in liquid nitrogen, retaining its fertilizing capacity for up to 3-4 months, and a fertilization rate of around 65% (controls 73%). After 18 months, the fertilization rate was 67.7±7.1% while controls were 79.0± 1.4% (Pholprasith 1992).

Stock Enhancement

The Thai DOF has started the stock enhancement program of *P. gigas* since 1983. The objective of the stock enhancement program is mainly to conserve, retain or replenish stocks of *P. gigas* which are endangered. Furthermore, stock enhancement of *P. gigas* aims to maintain fisheries productivity of a water body (especially in the reservoir) at the highest possible level.

At present, the stocking strategy is not based on any scientific principle. The stocking size is from 3 to 20 inches in total length. In the Mekong River, only offspring from wild broodstock were stocked. In the years when more than one pair of broodstock were induced to spawn, fingerlings from all broodstock were mixed and released. However, if only one pair of broodstock were spawned, the offspring were mixed with those produced in the previous years to ensure that the genetic diversity of the wild fish would not decrease. Also, fingerlings stocked into the Mekong River have been limited to the lowest possible number until the population structure has been determined. At present, around 60,000 fingerlings have been stocked in the Mekong River. The stocking sites were not confined only to its spawning ground in Chiang Khong, but every province along the Mekong River was included (Fig. 3).

In inland water bodies like reservoirs, fingerlings will be tagged before stocking to identify their origin. Stocking will be conducted only in large water bodies with established conservation programs. The stocking density is one fish per 30 rai (5 ha). Catches are monitored annually. From 1984 to 2004, more than 100,000 Mekong giant catfish fingerlings have been released into reservoirs throughout Thailand.

Tagging

Various types of tagging techniques have been applied to the Mekong giant catfish in order to study its behavior and migration route. Fin clipping, hot branding and Spaghetti tags are found to be useful only for short-term studies since these marks or tags change or are removed accidentally as the fish grows fast. Preliminary studies using ultrasonic biotelemetry technique (by implanting with coded ultrasonic transmitter tags and monitoring tags by means of ultrasonic receivers) seem to be very promising. However, long-term monitoring using this technique is very costly and requires cooperation from the riparian countries along the Mekong River.

Production from reservoirs

Recently, the Thai DOF has started to monitor catches of *P. gigas* in reservoirs. The results from a study in 2004 showed that only 2% (1,500 of 64,000) of stocked fish were recaptured in 10 reservoirs throughout the country. The total weight of fish was 64.2 tonnes with a value of 4.79 million Baht (0.12 million USD) (Fig. 4).

Population Genetics Studies

Reduced genetic variation causes a decrease in the ability of a population to adapt to and withstand normal environmental challenges. Therefore, for a population to avoid extinction in the longer term, it is essential that appropriate and sufficient genetic variation be maintained. This becomes an issue particularly when breeding fish for release into the wild. Since 2000, genetics of *P. gigas* has been studied to determine the genetic structure of the wild fish and develop a broodstock management plan for both restocking programs and aquaculture. Microsatellite DNA (msDNA) and mitochondrial DNA (mtDNA) markers have been developed. Genetic variability of wild and captive stocks was estimated using both markers. Stock inventory for hatchery fish is being conducted to develop a broodstock management plan and reconstruct the genotype of the wild stock using the genetic structure of the founder populations in the hatchery.

Conclusion

There has been very little evaluation of the recapture data and no demonstration

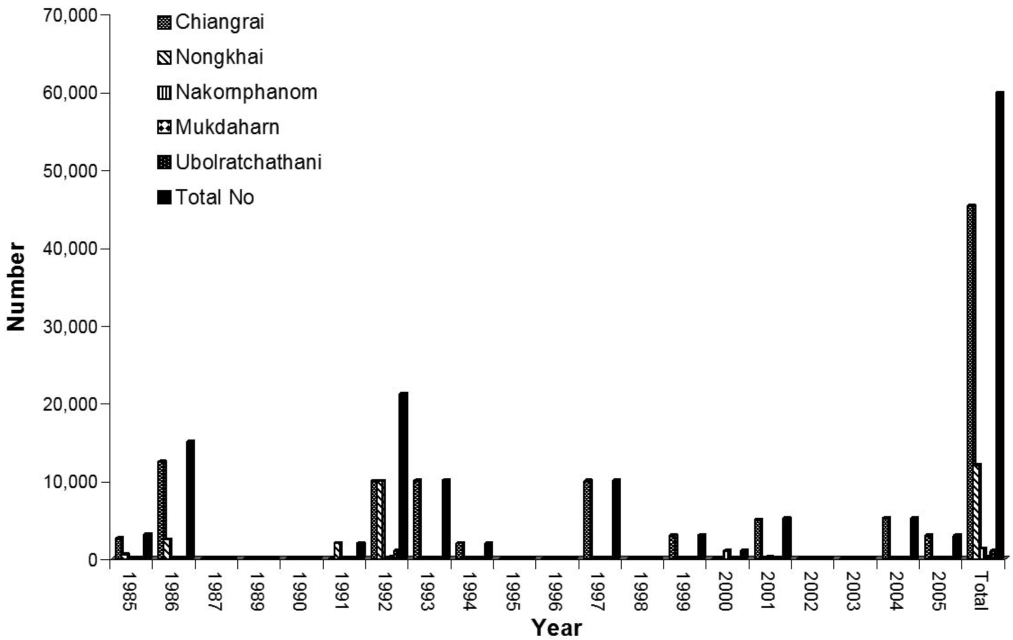

Fig. 3. Number of Mekong giant catfish fingerlings released into the Mekong River at Chiangrai, Nongkhai, Nakornphanom, Mukdaharn and Ubolratchathani, 1985-2004.

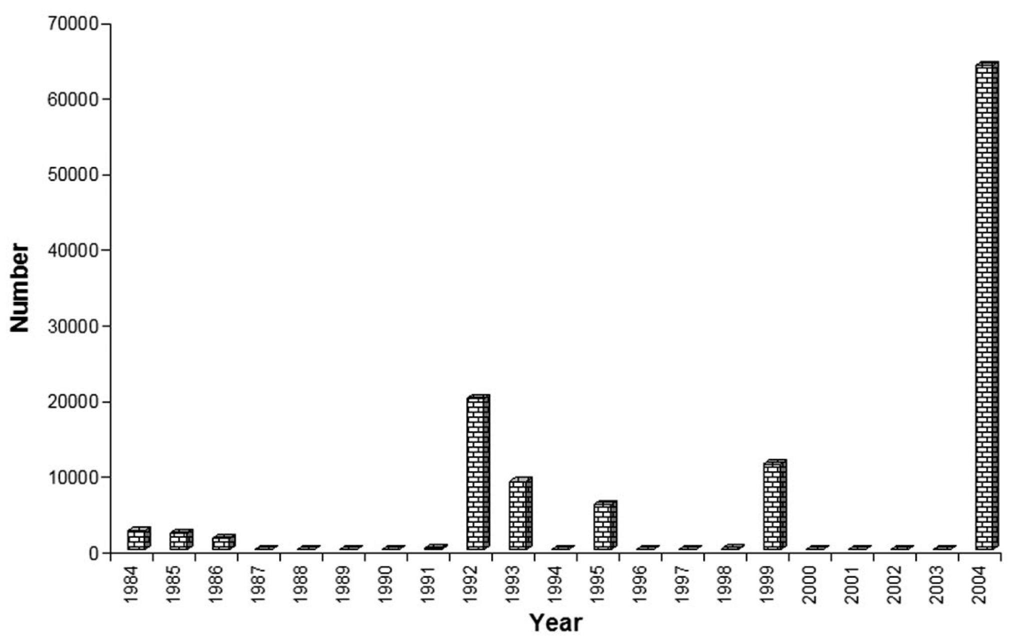

Fig. 4. Number of Mekong giant catfish fingerlings released into reservoirs throughout Thailand, 1984-2004.

of the economic viability of stock enhancement of Mekong giant catfish in inland water bodies. Inspite of these, stock enhancement of the Mekong giant catfish in inland water bodies seems to be very successful. However, for conservation purposes, more genetic studies are needed to support a suitable restocking program that will not affect natural stocks of *P. gigas* in the Mekong River. Furthermore, it is suggested that any management aimed at improving the situation of threatened species or reintroduction of extinct species must start by the identification of the possible reasons for rarity (Mattson et al 2002). If these prove to be unsuccessful, efforts aimed at improving or re-establishing populations are likely to fail as well. Notably, this implies that stocking aimed at re-inforcement/supplementation or re-introduction of a threatened or extinct species should only be considered after the factors that cause rarity have been identified and resolved.

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Organization and Development of Stock Enhancement in Japan

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Introduction

In the 1960s, the Japanese economy was starting to industrialize. The rapid increase in business investment in new factories and equipment stimulated a yearly economic growth rate of approximately 12% (METI 1970). However, these developments have disrupted coastal landscapes through land reclamation and industrial effluents (Fishery Agency 1980a). Furthermore, overfishing has accelerated with increased consumer spending and demand for fish protein. Consequently, coastal fish resources such as red sea bream (*Pagrus major*), kuruma prawn (*Marsupenaeus japonicus*) and swimming crab (*Portunus trituberculatus*) have been depleted and income of coastal fisherfolk has decreased (Fishery Agency 1980b). Under such conditions, the Japanese government initiated the Stock Enhancement Program in 1963 (Fishery Agency 1980c, Imamura 1999).

The program initially targetted red sea bream and kuruma prawn in the Seto Inland Sea in southern Japan which covers almost 3,000 islands (Imamura 1999). Because the fundamental concept of stock enhancement programs was to compensate juvenile loss caused by high larval mortality in the ocean, development of mass juvenile production techniques was emphasized (Fishery Agency 1980a, Matsuoka 1989). Therefore, the release of juveniles became a typical form of stock enhancement in Japan.

The current number of target species for stock enhancement has increased to almost 80 species. Stock enhancement is undertaken by both the national government and local governments together with conservation of fishing ground and regulation of fish catches for resource management (Resource Association 1983a, Imamura 1999, Fishery Agency 2000, JASFA 2003a). This article reports the present status of stock enhancement in Japan from the organizational and technical viewpoints.

Organizations

At present, there are 16 national and 177 local hatcheries operated by national and local governments in Japan. The national hatcheries aim to develop stock enhancement techniques, and mainly target migratory species which are chosen based on their resource levels and local government requests (Fushimi 2001, JASFA 2003a). Local hatcheries carry out the stock enhancement programs for local species using techniques developed by the national hatcheries (Imamura 1999). In some cases, national hatcheries and neighboring local hatcheries cooperate to evaluate the effectiveness of stock enhancement (Fishery Agency 2002). Similarly, stock enhancement of sedentary species has also been promoted by the local hatcheries in response to requests from regional fisherfolk (Agatsuma 2005, Toba 2005, Maru and Kosaka 2005, Sasaki 2005). Consequently, such stock enhancement programs have covered 36 fish species, 15 crustacean species, and 20 mollusk species with annual releases of 80 million fish, 300 million crustaceans, and 14 billion mollusks (Tables 1 and 2).

Table 1. Fish and crustaceans targeted in the stock enhancement programs of Japan.

	Family	Scientific name	Common name
Fish	Branchiostegidae	*Branchiostegus japonicus*	Japanese tilefish
	Carangidae	*Pseudocaranx dentex*	Striped jack
		Seriola quinqueradiata	Yellowtail
	Clupeidae	*Clupea pallasii*	Pacific herring
	Gadidae	*Gadus macrocephalus*	Pacific cod
	Haemulidae	*Parapristipoma trilineatum*	Chicken grunt
	Lethrinidae	*Lethrinus nebulosus*	Spangled emperor
	Paralichthyidae	*Paralichthys olivaceus*	Japanese flounder
		Lateolabrax japonicus	Japanese seaperch
	Platycephalidae	*Platycephalus indicus*	Bartail flathead
	Pleuronectidae	*Pleuronectes herzensteini*	Littlemouth flounder
		Pleuronectes schrenki	Cresthead flounder
		Pleuronectes yokohamae	Marbled flounder
		Tanakius kitaharae	Willowy flounder
		Verasper moseri	Barfin flounder
		Verasper variegatus	Spotted halibut
	Sciaenidae	*Nibea japonica*	Japanese meagre
	Scombridae	*Scomberomorus niphonius*	Japanese Spanish mackerel
		Thunnus orientalis	Pacific bluefin tuna
	Scorpaenidae	*Sebastes inermis*	Black rockfish
		Sebastes oblongus	Oblong rockfish
		Sebastes pachycephalus	Spotbelly rockfish
		Sebastes schlegeli	Korean rockfish
		Sebastes thompsoni	Goldeye rockfish
		Sebastes vulpes	Fox jacopever
		Sebastiscus marmoratus	Japanese stingfish
	Serranidae	*Epinephelus akaara*	Hong Kong grouper
		Epinephelus bruneus	Longtooth grouper
		Epinephelus septemfasciatus	Convict grouper
		Plectropomus leopardus	Leopard coral grouper
	Sparidae	*Acanthopagrus australis*	Surf bream
		Acanthopagrus schlegeli	Black porgy
		Pagrus major	Red seabream
	Synanceiidae	*Inimicus japonicus*	Devil stinger
	Tetraodontidae	*Takifugu rubripes*	Ocellate puffer
	Trichodontidae	*Arctoscopus japonicus*	Sailfin sandfish
Crustaceans	Penaeidae	*Penaeus japonicus*	Kuruma prawn
		Penaeus semisulcatus	Green tiger prawn
		Penaeus chinensis	Fleshy prawn
		Metapenaeus ensis	Greasyback shrimp

Table 1 (continued from p. 92)

Family	Scientific name	Common name
Pandalidae	*Pandalus kessleri*	Hokkai shrimp
	Pandalus hypsinotus	Humpback shrimp
Palinuridae	*Panulirus japonicus*	Japanese spiny lobster
Lithodidae	*Paralithodes brevipes*	Spiny king crab
Majidae	*Chionoecetes opilio*	Snow crab
Cheiragonidae	*Erimacrus isenbeckii*	Hair crab
Portunidae	*Scylla paramamosain*	Mud crab
	Scylla serrata	Mangrove crab
	Portunus trituberculatus	Swimming crab
	Portunus pelagicus	Flower crab
Grapsidae	*Eriocheir japonicus*	Mitten crab

From Fishery Agency et al (1993-2003)

Fish and crustaceans

Among 36 fish species, the major ones are the Japanese flounder (*P. olivaceus*) and red sea bream (*P. major*) with annual releases of about 25 and 20 million seedlings, respectively (Fig. 1). Stock enhancement programs for these two species are mainly promoted by local hatcheries and have attained commercial success in limited areas (Imai 1996, Fujita et al 1993). Besides, the stock enhancement effectiveness of those species has been jointly evaluated by the local hatcheries with the financial aid of the Japanese government (Imai 1996, Fishery Agency 2002). Recently, such joint evaluation has been applied to the Pacific herring (*C. pallasii*), ocellate puffer (*T. rubripes*), and Japanese Spanish mackerel (*S. niphonius*) (Fishery Agency 2002).

Among 15 crustacean species, the greatest focus is on the kuruma prawn (*M. japonicus*). Over 200 million individuals are released annually mainly in southern Japan (Fig. 2). In particular, local institutions around the Sea of Ariake have undertaken initiatives for the stock enhancement of the prawn (Morikawa et al 2003). In addition, the swimming crab (*P. trituberculatus*) and greasyback prawn (*M. ensis*) have been released by national and local hatcheries in the Seto Inland Sea and the Sea of Ariake (Fishery Agency et al 1993-2003).

Mollusks and other species

Only local hatcheries promote the stock enhancement of mollusks. Among 20 mollusk species, the numbers of individuals released annually are huge for scallop (*Patinopecten yessoensis*) and Japanese littleneck clam (*Ruditapes philippinarum*) - 3 and 10 billion, respectively (Fig. 3). The scallops are released only in the coast of Hokkaido and in Mutsu Bay by local hatcheries, and the littlenecks mainly in Tokyo and Ise Bays by fisherfolk unions (Resource Association 1983b, 1983c, Maru and Kosaka 2005, Toba 2005). These stock enhancement programs have been successful in each stocking region (Maru and Kosaka 2005, Toba 2005). The littlenecks are sometimes released for recreational shellfish gathering of visitors (Toba 2005). Besides, six of the 20 mollusk species are abalones which have high market value

Table 2. Shellfish, sea urchins, sea cucumbers, and cephalopod targeted in the stock enhancement programs of Japan.

	Family	Scientific name	Common name
Shellfish	Haliotidae	*Haliotis aquatilis*	Japanese abalone
		Haliotis diversicolor	Variously colored abalone
		Haliotis discus discus	Disk abalone
		Haliotis discus hannai	Ezo abalone
		Haliotis madaka	Giant abalone
		Haliotis gigantea Gmelin	Disk abalone
	Trochidae	*Tectus niloticus*	Commercial trochus
	Turbinidae	*Turbo cornutus*	Horned turban
		Turbo marmoratus	Great green turban
	Buccinidae	*Neptunea polycostata*	Ezo neptune
		Balylonia japonica	Ivory shell
		Fusinus perplexus	Perplexed spindle shell
	Arcidae	*Scapharca broughtonii*	Ark shell
	Pectinidae	*Patinopecten yessoensis*	Yezo scallop
	Tridacnidae	*Tridacna crocea*	Crocea clam
	Veneridae	*Meretrix lamarckii*	Hard clam
		Ruditapes philippinarum	Japanese littleneck
	Mactridae	*Pseudocardium sachalinense*	Sakhalin surf clam
		Tresus keenae	Trough shell
	Solecrutidae	*Sinonovacula constricta*	Razor clam
Sea urchins	Arbacia	*Tripneustes gratilla*	Collector urchin
		Pseudocentrotus depressus	Red seaurchin
	Echinoidea	*Anthocidaris crassispina*	Hard-spined sea urchin
	Strongylocentrotidae	*Hemicentrotus pulcherrimus*	Elegant sea urchin
		Strongylocentrotus intermedius	Intermediate sea urchin
		Strongylocentrotus nudus	Naked sea urchin
Sea cucumber	Holothuroidea	*Stichopus joponicus*	Japanese common sea cucumber
Cephalopod	Octopodidae	*Octopus vulgaris*	Common octopus

From Fishery Agency et al (1993-2003)

in Japan (Table 2). They are released by local hatcheries in all coastal areas of Japan due to strong requests from regional fisherfolk (Sasaki 2005). Sea urchins and sea cucumbers are important target species of regional stock enhancement programs with approximately 80 million seedlings released annually by 50 local hatcheries (Fishery Agency et al 1993-2003).

Technical Process

The technical aspects of stock enhancement can be classified into several phases, namely; spawning, seed production, tagging, release, and survey. Among these, seed production and survey of effectiveness of stock enhancement techniques have developed

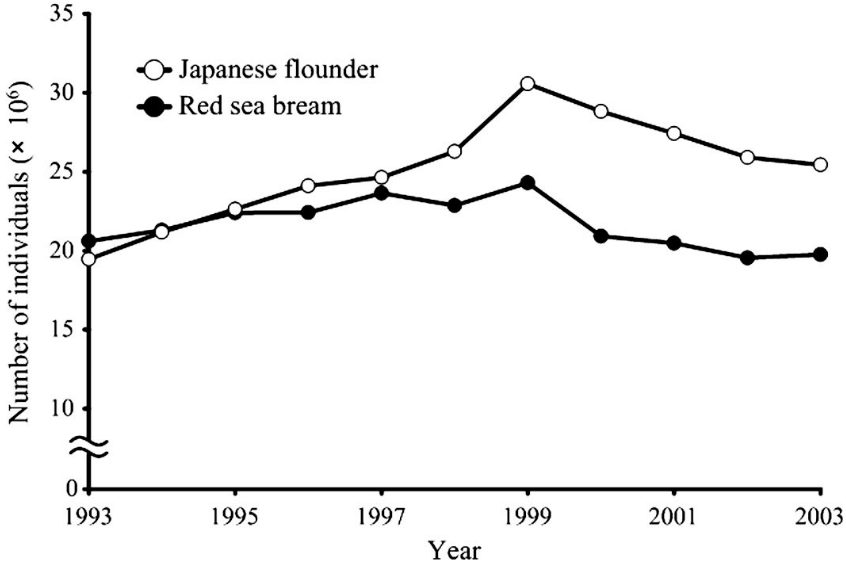

Fig. 1. Annual numbers of released individuals of Japanese flounder and red sea bream in Japan (data from Fishery Agency et al 1993-2003).

remarkably in the past two decades. Moreover, disease prevention and conservation of genetic resources in seedling populations have become recent issues.

Spawning, seed production and release

Wild fish and crustaceans from the management area of a stock enhancement program are used as broodstock (Mushiake et al 2003, Yano 2005). Most wild fish need to be reared for several months or years before they are induced to spawn by hormonal treatment, control of water temperature, and/or control of photoperiod (Hirose 1991, Mushiake et al 2003). Artificial fertilization is performed according to the need of each stock enhancement program (Mushiake et al 2003). Among crustaceans, mature females that have mated are obtained from the wild to supply fertilized eggs (Yano 2005, Hamasaki 2005). Spawning of females is synchronized by regulating water temperature (Yano 2005, Hamasaki 2005).

Mass seed production is usually performed in 50– to 350– mt concrete tanks with air and water supply systems and water heating equipment. Generally, 10,000 to 20,000 eggs per mt are placed in the tank for mass seed production (K. Teruya, personal communication). Water flow in a tank is controlled by means of aeration to distribute eggs and larvae uniformly (K. Teruya, personal communication).

The first larval diets consist of rotifers and brine shrimp; the more advanced stages are fed artificial diet (Fushimi 2001, JASFA 2003b). The nutritional value of rotifers and brine shrimp is usually enhanced by feeding highly unsaturated fatty acids (HUFAs) including docosahexaenoic acid (DHA) (Fushimi 2001). Besides, three different-sized rotifer species - *Brachionus plicatilis*, *B. rotundiformis*, and *Brachionus* sp. - are used according to the mouth size of larvae (Hino et al 2000). Conditions in the rearing tanks are checked daily including water temperature, pH, dissolved oxygen, food intake of the seed and swimming activity of rotifer. Rotifer supply is considered to be crucial for the success of mass seed production.

Seeds which have grown large enough for release are transported by boat or truck

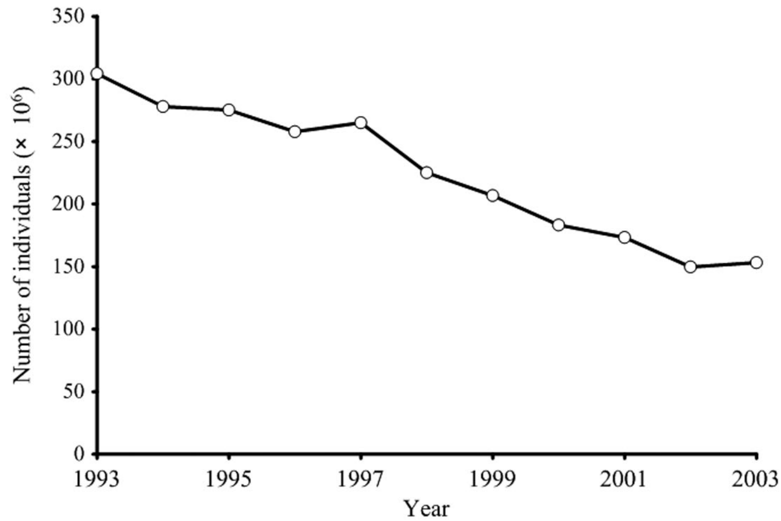

Fig. 2. Annual numbers of released individuals of kuruma prawn in Japan (data from Fishery Agency et al 1993-2003).

to a release point. The seed are sometimes acclimatized to the natural environment in net cages settled in the ocean for several days or months prior to release (Tanida et al 2003, JASFA 2003b). In striped jack (*Pseudocaranx dentex*), continuous feeding of artificial diets after release is useful for such acclimatization by regulating their dispersal from the release area to the ocean (Kuwada et al 2004).

Tagging and survey

Various tags have been used in stock enhancement programs. External tags, such as fin or caudal appendage cuttings, branding iron, dart tag, and disc and ribbon type tags, are commonly used to examine the distribution of released fish and prawns (Achiha 2004, Tanida et al 2003, Fujimoto et al 2001, Takeno et al 2001). The effectiveness of stock enhancement is usually evaluated by the fin or caudal appendage cuttings and the branding iron because these tags are relatively stable and easy to use. Similarly, Alizarin complexone (ALC) is used by many cooperative stock enhancement programs as an internal tag to distinguish the source of the released fish seed (Takemori et al 2005, Sasaki et al 2002, Okouchi 2003).

Cost effectiveness of stock enhancement is estimated based on the price and the number of marked seedling sold in fish markets (Kitada 2001). The daily number of recaptured seedlings is checked for several years in all the fish markets which sell fishery products from the stocking area (Kitada 2001, Okouchi 2003). Information on fishing grounds and fishing gears are also collected to standardize fishing effort among the markets (Kitada 2001, Okouchi 2003). Such information can sometimes contribute to the improvement of stock enhancement technology.

Disease prevention

While mass seed production has been successful in many species, infectious diseases have often caused mass mortality of larvae (Muroga 1995). In particular, viral diseases, such as Viral Nervous Necrosis (VNN) in striped jack and some other fishes, White Spot Disease (WSD) in kuruma prawn, and viral ascites in yellowtail have caused major damage to the stock enhancement programs of the host species (Munday 2002, Satoh et al 1999, Sorimachi and Hara 1985). Many bacterial diseases such as vibriosis, pasteurellosis, gliding bacterial infection, and bacterial enteritis

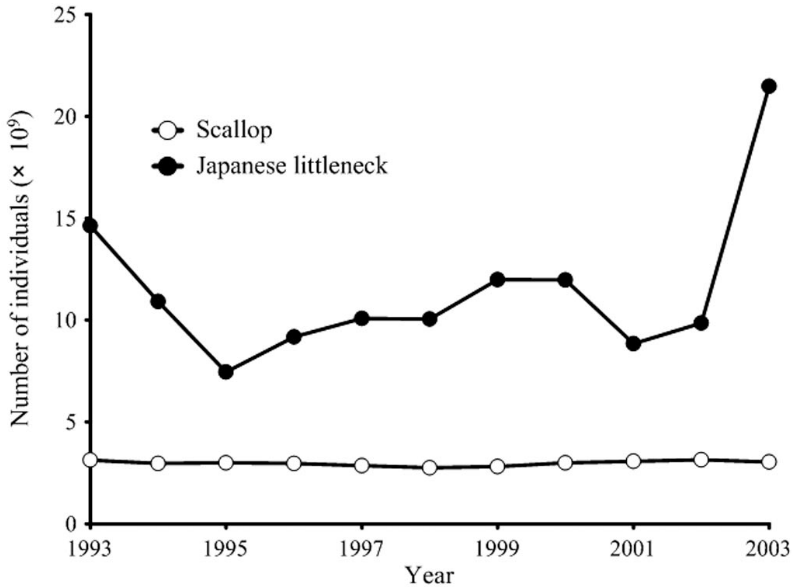

Fig. 3. Annual numbers of released individuals of scallop and Japanese littleneck clam in Japan (data from Fishery Agency et al 1993-2003).

with *Vibrio* sp. are additional obstacles in mass seed production (Muroga 1995). Sterilization by ozone or ultraviolet rays of the seawater used for production has become popular in recently established hatcheries to keep out disease agents from the ocean. At the same time, there is growing awareness that sanitary supervision, e.g., strict assignment of tools and workers to a given tank, is important to prevent and control diseases in the hatchery.

However, seawater sterilization has not always been effective for viral diseases because they can be transmitted by the broodstock. For example, VNN and WSD are known to occur in larvae and juveniles via vertical transmission (Munday 2002; Satoh et al 1999). Therefore, recent seedling production has selected broodstock based on diagnosis by polymerase chain reaction (PCR) techniques (Nishizawa 1994, Satoh 2001, Mori 1998). PCR diagnosis checks for the presence of viral nucleic acids in ovarian eggs or the thelycum (Mori 1998). Moreover, such molecular biological techniques are now being applied to epidemiological analysis in the hatchery (Sugaya et al 2005).

Prevention of disease transmission from hatchery fish to wild fish is very important for responsible stock enhancement. Therefore, hatcheries check for the presence of disease agents and viruses in seedlings before their release.

Genetic variability

In many target species for stock enhancement program, the seedlings have usually low genetic variability and altered genetic composition relative to the wild population due to limited numbers of broodstock. Such phenomenon has led the concern that released seedlings might decrease the genetic variability of the wild populations and disturb the locally adopted gene pools (FAO 1993, Campton 1995).

From this points of view, most hatcheries gather from the stocking area 50-200 wild individuals for broodstock of Japanese flounder (*P. olivaceus*) and red sea bream (*P. major*) to reflect the regional genetic composition and variability (T. Nishioka, personal communications). These broodstock are partially replaced every 3-5 years (Mushiake et al 2003). Furthermore, recent development of highly polymorphic DNA markers, such as microsatellites DNA and mitochondrial DNA markers are about to bring a new strategy for the genetic management of the broodstock. The selective breeding according to the minimal-kinship criterion, which can be evaluated by pedigree analysis based on DNA markers, has been reported to be effective for the genetic conservation even in small number of broodstocks (Sekino et al 2003, Taniguchi 2004, Ortega-Villaizán Romo et al 2006).

Future Directions

The stock enhancement program activities that started in the Seto Inland Sea have been expanded in the last four decades to cover the rest of Japan. Mass seed production techniques have been established in almost 80 species and have contributed to the expansion of the stocking program. In several species such as scallop, kuruma prawn and red sea bream, stock enhancement has been successful economically in some areas. In contrast, the effectiveness of stock enhancement has not been evaluated for many other target species because of the complexity of the fishery and fluctuations in the natural populations of the species.

Current stock enhancement in Japan has recently improved with the development of the fish market survey method to estimate effectiveness of stock enhancement. Joint studies have been organized among local and national hatcheries for the precise estimation of stock effectiveness using the marker survey method. Although there are still difficulties in this method due to the complexity of the fishery, these studies will supply valuable information about stock enhancement effectiveness. Furthermore, the information might contribute to more effective combination of stock enhancement, conservation of fishing ground and regulation of fish catches for proper resource management.

Acknowledgement

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Fisheries, Aquaculture and Stock Enhancement in Lao PDR

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Introduction

Fisheries development in Lao PDR is confined to inland fisheries development and sustainable freshwater aquaculture including culture-enhanced capture fisheries and fishery-enhanced aquaculture. Given the potential of water, wetland and aquatic resources and the magnitude of decline in fish catches from the Mekong River and its tributaries, the Government of Lao PDR has given priority to fisheries development with strong concern for sustainable aquaculture. The overall policy framework is therefore geared toward the sustainable use, appropriate management and protection of natural resources: forest, land and water resource including aquatic biodiversity. The national goal for fisheries development during the last decade was focused on how to increase fish production from aquaculture while maintaining capture fisheries, recognizing that about 50% of the dietary protein of Lao people comes from living aquatic resources which are important for food security of the nation.

Endangered Species in Fisheries

According to Article 18 of the Regulation of the National Conservation Forest, Aquatic Animal and Wildlife (Reference No. 0524/MAF.2001, 7 June 2001), endangered aquatic animals and wildlife in Lao PDR are classified into two categories:

1) Protected species – rare aquatic animals and terrestrial wildlife with high conservation value, importance and usefulness to society (Table 1). Fishing and hunting of protected species are prohibited for all seasons.

2) Controlled species – rare aquatic animals and wildlife whose populations are threatened

Table 1. List of protected freshwater species.

Lao name	English name	Scientific name
Pa kha	Irrawaddy dolphin	*Orcaella brevirostris*
Pa phalay	Sting ray	*Dasyatis laosensis*
Pa kouang	Croaker	*Boesemania microlepis*
Pa beuk	Giant catfish	*Pangasianodon gigas*
Pa leum		*Pangasius sanitwongsei*
Pa seua	Tiger perch	*Datnioides pulcher*
Pa laifaitfa	Electric eel	*Anguilla marmorata*
Pa meo		*Setipinna melanochir*
Pa eun khao	Thicklip barb	*Probarbus labeamajor*
Pa bou	Gobies	*Oxyeleotris marmorata*
Pa kheung		*Hemibagrus wykoides*

Table 2. List of controlled freshwater species.

Lao name	English name	Scientific name
Pa souay	Pangasius	*Pangasius krempfi*
Pa fa ong	Freshwater turtle	*Amyda* spp.
Pa khoun		*Wallago marmorata*
Pa deng		*Tor* spp.
Pa nang deng		*Hemisilurus*
Pa phone		*Cirrhinus microlepis*
Pa makway		*Luciosoma* spp.
Pa keng		*Cirrhinus molitorella*

with extinction. People can use these species for home consumption but not for large scale harvesting or trade. Fishing and hunting are not allowed during the breeding season.

There is insufficient information regarding the current status of the protected and controlled aquatic species in Lao PDR. Many are most likely in critical status, while others may require a review of their conservation status. Based on Tables 1 and 2, only three species are included in the CITES list: *Orcaella brevirostris* (Pa kha), *Pangasianodon gigas* (Pa beuk) and *Probarbus labeamajor* (Pa eun khao).

Why endangered?

With the country's vast water resources, a large number of indigenous species is present within the different ecosystems. The Mekong River and its tributaries have been heavily fished resulting in the decline and endangered status of many species especially the Mekong River Irrawaddy dolphin at the Cambodia-Lao PDR transboundary pool. The Government of Lao is a CITES member and retains internationally important populations of many declining and otherwise threatened species.

The causes for declining species are as follows:

1) Illegal fishing (electro-fishing and no seasonal fishing)
2) Harassment from tourist, fishing and passenger boats in the dolphin areas
3) No dolphin management committee
4) Use of gill nets (all mesh sizes)
5) Overfishing and increase in number of fishers (especially large scale commercial fisheries)
6) Use of explosives
7) Shallowing of deep pools due to sedimentation and habitat change
8) Water pollution from oil and mining
9) Noise problems created by fast boats
10) Natural death and disease

Status of Seed Production Technology of Freshwater Species

Aquaculture development in Lao PDR has been a tradition with lessons learned from neighboring China, Vietnam and Thailand. The seed farms were built in many provincial capitals especially in Vientiane, Savannakhet, Pakse, Sayeboury, Louang Prabang, Houaphanh, Xiengkhouang and Oudomxay. As of 2001, there were 30 existing hatcheries (17 government-managed and 13 privately run farms), and 9 are under construction. This will be the basic infrastructure for expansion of aquaculture in the near future.

Broodstock development and management

The basic element of profitable fish production is sufficient and good quality breeding material including brood fish, eggs, larvae, fry and fingerlings for supply to the farmers. The important parts of broodstock management are:

1) Procurement, development, rearing and maintaining of broodstock
2) Provision of optimal living conditions for broodstock and young
3) Selection and basic genetic improvement of broodstock
4) Preparation of spawners for reproduction
5) Development of breeding program and providing good quality seeds to the farmers

Broodstock management as a substantial component of fish farming depends on hatchery managers, technicians and fish farmers who maintain, select, and produce the broodfish. Hatchery managers should take care of all the responsibility of breeding work. Environmental conditions during rearing also strongly determine the spawning potential of broodfish, feeding management and handling methods.

Nursery systems

The recommended stocking rate for one-week old fish fry commonly cultured in the country are 400-500/m^2 in earthen ponds (more then 60 cm water depth) and 250/m^2 in cement tanks (more than 50 cm water depth). Fish fry are stocked at these densities for up to one month or until they reach a size of 2-3 cm, after which densities are reduced since competition for food and space will increase quickly, and growth and survival of the fry could decline. Once the fry reach 2-3 cm, intensive nursing in net cages is an option if flowing water and aeration are available.

Legislation

The Lao PDR government has given emphasis to fisheries and aquatic resources management, while other related laws covering forestry, land, water, and environment have also been formulated in support of fisheries management. Fisheries management functions have been decentralized and local authorities have been assigned to ensure the conservation of natural resources and development of fish farming. Local authorities are responsible for promoting public awareness on the adverse impacts of illegal and destructive fishing gears, sustainable exploitation, use of indigenous fish and non-carnivorous species, and the careful use of exotic species in aquaculture.

Fisheries management measures have been enforced by local authorities and communities themselves with many prejudices, conflicts and problems. It was due to unverified scientific information responding to the causes of the problems at the grassroots level. For this reason, the Prime Ministerial Decree 118 (5 October 1989) concerning the management and conservation of terrestrial and aquatic animals, as well as regulation of fishing and hunting activities, was declared and enforced.

At present, regulatory policies for aquaculture and fisheries have not been formulated. There is a need to establish appropriate laws in aquatic resource management, development and research in the country.

Stock Enhancement

With the increase in economic development and growth in both domestic and regional trade, the demand for fish has likewise increased. It is believed that increased production from capture fisheries may not be possible, so it has to come from aquaculture or enhancement of fisheries. Viable fish farming systems and management practices have been promoted, with more focus on rural aquaculture, e.g., fish seed production and nursery, small-scale fish culture in pond, rice-cum-fish farming, enhancement of communal water bodies, integrated fish-livestock farming, extensive to semi-extensive cage culture of fish, and environmentally sustainable commercial fish farming.

National restocking/stock enhancement program

Fisheries and aquatic resources in Lao PDR are also of immense importance in restocking, if we consider more than one million hectares of water resources from the Mekong River and its tributaries, swamps, rainfed ricefields, flood plains, reservoirs (natural and man-made), and other wetlands. Capture fisheries resources have been declining. For sustainable use of aquatic resources, the Forestry Law (Reference No. 01-96 dated 10 November 1996, Article 46) declared 13 July of each year as the day for releasing fish and protecting aquatic animals and wild life. The current stocking rates in natural water resources are generally low due to a shortage of seedstock. However, about 34.5 million fish were stocked in lakes and reservoirs throughout the country last 1-13 July 2004. The species were mostly tilapia, *Cirrhinus microlepis* (Pa phone), *Brobarbus jullieni* and *Hypophthalmicthys nobilis* (Bighead carp).

The development program of aquaculture in Lao PDR is focused on the following activities:

1. Rehabilitation of fish hatcheries and expansion of fish seed production and distribution
2. Development of small-scale breeding facilities at local level
3. Development of rural aquaculture
4. Improvement of fish feed

Strategies

Fisheries and aquatic resources research and development should concentrate on resource assessment and also community studies, aquaculture and extension. Therefore, short and long-term research and development priorities for the fisheries sub-sector should focus on the sound management of declining harvests from rivers and reservoirs, minimizing impacts, and preserving aquatic biodiversity. Different forms of aquaculture must be promoted, especially of species which are preferred by local folk and which comprise most of the total fish production in the country. Government programs should be geared towards the promotion of low-input technologies such as rainfed rice-cum-fish and integrated small fish culture, which are well within the reach of marginalized fish farmers in the rural areas.

Capture fisheries

Appropriate strategies for fisheries management should be based on the Code of Conduct for Responsible Fisheries (FAO 1995), Convention on Biological Diversity (particularly its implications for fisheries management), and Convention on Migratory Species.

In the context of Lao PDR and the Lower Mekong Basin, there is still a need for greater understanding of the physical and socio-economic settings of present endowments in aquatic resources. Riverine ecology, taxonomy, fish life cycle, fish habitats and breeding grounds, aquatic plants and animals, and wetland values need to be indentified and reassessed.

For best management practices, some key factors should be considered such as:

1. Centralization of fisheries management functions to empower local communities to participate in co-management functions using local knowledge and effective traditional management systems
2. Implementation of policies that prohibit illegal and destructive fishing gears and practices, by building awareness on adverse impacts, enforcement of regulation and encouragement of alternative means of livelihood
3. Introduction of rights-based fisheries in some important reservoirs and fishing grounds

4. Promotion of the importance of freshwater fisheries for local food security, rehabilitation and restoration of habitats for migratory fish, restocking of indigenous fish species, and promotion of culture-based freshwater fisheries, where appropriate
5. Use of national statistical systems by focusing on clear objectives and results directly related to fishery management decision-making and planning processes

Aquaculture

For the development of aquaculture in Lao PDR, the basic principle adhered to is poverty alleviation covering aspects of social equity, gender equity, environmental sustainability, economic viability and good governance. Among the key elements identified during the February 2000 Conference on Aquaculture in the Third Millennium is The Bangkok Declaration and Strategy. At this stage of aquaculture development, Lao PDR should incorporate the following elements in the government's development strategies:

1) Invest in aquaculture development
2) Integrate aquaculture into rural development
3) Manage aquaculture health
4) Apply genetic methods in aquaculture
5) Improve nutrition in aquaculture
6) Improve food fish quality and safety
7) Promote market development and trade
8) Strengthen institutional support
9) Strong regional and inter-regional cooperation

Monitoring

Monitoring of fisheries and aquaculture management include the following:

1) Establish and implement comprehensive policies for innovation in fisheries management
2) Develop measures to prevent unauthorized fishing and eliminate the use of illegal and destructive fishing gears, build awareness of their adverse impacts, develop and promote responsible and selective fishing gears and practices, enforce regulations and encourage alternative means of livelihood
3) Investigate the potential of under-utilized fisheries resources and promote their exploitation in a precautionary manner based on the best available scientific information under rights-based fisheries regimes
4) Coordinate and decentralize collection and use of fisheries-related statistical data among national fisheries and other authorities, including those responsible for food, trade, vessel registration, aquaculture and rural development
5) Develop national statistical mechanisms for the exchange of statistical data and related information
6) Ensure production of high quality seeds, develop domesticated broodstock and promote responsible collection and use of wild broodstock and seeds
7) Reduce the risks of negative environment impact, loss of biodiversity and diseases
8) Build human resource capabilities for environment-friendly aquaculture

Government agencies and NGOs involved

For fisheries development and management and sustainable aquaculture, the Ministry of Agriculture and Forestry, and Department of Livestock and Fisheries cooperates with the Forestry Department, Irrigation Department, National Agriculture Research Institute and Science and Technology and Environment Agency. Over the last decade (1990-2000), numerous activities have been conducted with the valuable assistance and cooperation of many donor countries, international organizations and NGOs namely the Mekong River Commission, Fisheries and Agriculture Organization-United Nations Development Programme, Danish International Development Agency, International Development Research Centre of Canada, Japan International Cooperation Agency, Swedish International Development Agency, and Australian Center for International Agricultural Research.

More than 30 activities have been carried out for sound fisheries management and interventions in collaboration with other sectors, and private firms through bilateral, multilateral and regional assistance. These include inventories, assessment, biophysical studies of resources, surveys, socio-economic studies, community awareness, post-impoundment management, etc.

Co-management of fisheries

The process of establishing fisheries co-management in Lao PDR includes the following: field survey, data collection, meetings and discussion with farmers to find out problems, organizing the community, election of representatives from fisher groups, planning the activities to address the identified problems, implementation of activities, monitoring and evaluation of activities, and reviewing current plans and establishing new plans.

Conclusion

An expanding human population and poverty make the conservation of endangered species in Lao PDR difficult because poor people in rural areas still suffer from inadequate nutrition. The importance of indigenous fish species in Lao PDR and the value of food and income generated from capture fisheries have not been emphasized and made aware to the public. It is in this regard that people must be informed of their social responsibility to maintain and conserve fish biodiversity if only to protect this valuable food source.

Fishery Stock Enhancement in Malaysia

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Introduction

Stock enhancement is a management tool which alleviates problems that endanger natural resources. Endangered aquatic resources are broad issues that involve not only individual species but also the habitat and environment where they live and interact. Although measures are being undertaken to help specific cases, the universal problem of threatened aquatic species cannot be solved until humans protect their natural environments (Kurpis 2002). Species may become endangered due to overexploitation, habitat alteration and destruction, and overpopulation by alien species and other factors. Natural changes normally occur at a slow rate giving most organisms ample time to evolve and adapt to changes. However, drastic changes due to natural disasters, e.g., earthquakes or tsunamis, may halt adaptation and cause most individuals to die, or even lead to species extinction.

Species extinction is a global issue that requires all nations to practice sustainable management. This paper aims to examine the status of endangered fisheries species in Malaysia, and highlight some resource management initiatives including the restocking and stock enhancement program in the country. Its scope covers only aquaculture-based species, which is in line with the Program on Stock Enhancement for Species of International Concern being implemented by the Southeast Asian Fisheries Development Center/Aquaculture Department in the Philippines.

Table 1. List of endangered freshwater fish.

Scientific name	English name	Local name
Scleropages formosus	Golden arowana	Kelisa
Tor tambroides	Malaysian Mahsheer	Kelah
Probarbus jullieni	Jullien's golden-price barb	Temoleh

Endangered species

Freshwater vertebrates

At present, three indigenous species of freshwater fishes are protected by law in some States in Malaysia (Table 1). Thus far, no invertebrates have been listed for protection.

Brackishwater and marine invertebrates and vertebrates

To date, Malaysia protects 26 species of vertebrates including one fish, five reptiles and 20 marine mammals. In addition, four species of marine mollusks (invertebrates), all of which belong to the genus *Tridacna*, are included in the protection list. Several other species that are heavily exploited but have yet to be listed under the Malaysian marine protected species include sea cucumbers (in particular, *Stichopus* spp.) and seahorses (*Hippocampus* spp.) (Table 2). These species deserve urgent protection.

Volume of yearly catch for the last 10 years

Freshwater vertebrates

Although the two species of freshwater fish (*Tor tambroides* and *Probarbus jullieni*)

Table 2. List of endangered brackishwater and marine invertebrates and vertebrates.

Group	Scientific name	English name	Local name
Mollusks	*Tridacna gigas*	Giant giant clam	Kima gergasi
	Tridacna maxima	Large giant clam	Kima besar
	Tridacna crocea	Crocus giant clam	Kima
	Tridacna squamosa	Scaly/Fluted clam	Kima sisik
Fish	*Hippocampus* spp.	Sea horses	Kuda laut
Invertebrates	*Stichopus* spp.	Sea cucumbers	Gamat

are protected in a number of states, these fishes are still exploited for local consumption. The golden arowanas (*Scleropages formosus),* sought after as exotic fishes are found in both domestic and international markets. They are legally caught from rivers but their export is prohibited except the second filial generation (F_2) juveniles produced from artificial breeding. Unfortunately, annual catch statistics of all three species are not available. However, the estimated landings of all freshwater fishes, both from public water bodies and inland fisheries are presented in Table 3.

Brackishwater and marine invertebrates and vertebrates

The collection of giant clams for consumption is prohibited in islands that have been declared as marine parks. However, scattered illegal collection persists in some areas particularly in the Borneo part of Malaysia. Catch data is hardly available. The seahorses (*Hippocampus* spp.) and sea cucumbers (*Stichopus* spp.) have been sought-after species for medicines for decades. Seahorses are mainly exported, whereas *Stichopus* spp. are locally used. Compared to other fishery products, the volume of catches for these two groups of fishes is rather small and limited to a few selected areas hence, the data is hardly documented.

Fisheries Biology

Habitat, life cycle and feeding habits

Freshwater species

The sought-after ornamental species of arowanas are native to most undisturbed rivers in Malaysia. *S. formosus* is found to

Table 3. Estimated landings (mt) of freshwater fishes from both public water bodies/inland fisheries in Malaysia (excluding Sarawak State), 1994-2003.

Species	Landings (mt/yr)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
All freshwater fish species (Javanese carp, common carp, catfishes, black and red tilapias, etc.)	2,064	3,939	3,683	3,949	4,344	3,453	3,549	3,446	n/a	3,828

Table 4. Statistics of seed production of freshwater species and releases into public water bodies in Malaysia (excluding Sarawak State) for 1997-2003 (x 10^3 mt).

Species	Production (10^3 mt/year)						
	1997	1998	1999	2000	2001	2002	2003
All species (Javanese carp, Common carp, Giant freshwater prawns, River catfish and Red tilapias, etc.)	6,891	5,160	2,697	4.502	2,353	Not available	5,408

breed naturally in Krian River and Tasik Merah Lake in Taiping, Perak. The life cycle and other biological information of arowanas are well known and the breeding of this species is successful. On the other hand, Kelah (*Tor tambroides*) and Temoleh (*Probarbus jullieni*) are poorly studied (Ahmad-Ashar 1992).

Brackishwater and marine species

A number of ecological and biological studies on giant clams and sea cucumbers have been attempted by researchers from the Malaysian Department of Fisheries and local universities. Unlike giant clams and sea cucumbers, seahorses have received little attention from the scientific community.

Why endangered?

The Malaysian classification of endangered species follows the International Union for the Conservation of Nature categories and the Convention on International Trade in Endangered Species of Wild Fauna and Flora listings. However, there are species that need special attention as their populations have drastically declined. For example, the State of Perak has formulated laws to protect all three freshwater species listed in Table 1.

Status of seed production technology

Freshwater species

The technology for seed production of arowanas (*S. formosus*) is readily available in Malaysia. The production of F_2 and F_3 arowana juveniles by local aquaculturists was successful in the past ten years. However, seed production technology for Kelah and Temoleh species is still in its infancy. It is worth noting that there are established seed production technologies for Javanese carps, common carps, giant freshwater prawns, Red tilapia, River catfish and a few other freshwater fishes. Some 2,000–7,000 fry of these species are released annually into water bodies for conservation (Table 4).

Brackishwater and marine species

In Malaysia, seed production technology for brackishwater and marine vertebrate and invertebrate species, like the giant clams, sea cucumbers and seahorses, is still lacking. Therefore, data on seed production and releases for these species are not available.

Aquatic Resource Management

Fisheries laws and regulation

Enforcement at different levels

A number of laws and regulations are used to protect and manage aquatic fishery resources in Malaysia. A partial list of such legislation specifically addressing the issue of endangered resources follows:

- Fisheries Act 1985 (Act 317)
- Fisheries (Prohibition of Method of Fishing) Regulations 1980
- Fisheries (e.g., Prohibition of Import of Fish) Regulations 1990

Table 5. Existing sanctuaries and protected areas in Malaysia.

Sanctuary name	State in Malaysia	Species protected
Kelah (*Tor tambroides*) Sanctuary	Pahang (in National Park)	Freshwater fish/Kelah
Sungai Nenggiri Sanctuary	Kelantan (in National Park)	Freshwater fish/Kelah
Tasek Bukit Merah Sanctuary	Perak	Kelah, Arowana & other freshwater fish
Marine parks	Kedah, Pahang, Johor, Terengganu, Sabah and Sarawak	Coral reef ecosystems including giant clams, sea cucumbers, seahorses
Fisheries prohibited areas	Sarawak (P. Talang-Talang), Melaka (P. Besar), Negeri Sembilan (Tg. Tuan)	Mollusks, corals, fishes
No trawl zone (5 nm)	Entire country	All coastal species
State parks	All states	All terrestrial and aquatic organisms
National parks	Pahang, Terengganu Kelantan, Sarawak, Sabah	All terrestrial and aquatic organisms

- Fisheries (Prohibited Areas) (Rantau Abang) Regulations 1991
- Establishment of Marine Parks Malaysia Order 1994
- Fisheries (Prohibited Areas) Regulations 1994
- Fisheries (Control of Endangered Species of Fish) Regulations 1999
- State Fisheries (Riverine) Rules

Legislation and enforcement work at both Federal and State levels. In Peninsular Malaysia, the Department of Fisheries implements such laws for both levels. In Sarawak and Sabah, the enforcement is supplemented by some State laws and regulations.

Territorial use rights (TURFs)

Anything that is found on land and water areas up to three nautical miles (nm) is covered by State law whereas Federal law applies to aquatic areas beyond 3 nm. In addition, there are cases that involve both Federal and State levels, especially pertaining to fishery activities in 3 nm overlapping areas. Rights are given to some local communities to fish in protected areas using simple and traditional gears. For example, local island inhabitants are allowed to fish in the vicinity of Marine Parks, for their daily consumption using handlines.

Habitat protection and rehabilitation

Sanctuaries and protected areas

Establishing sanctuaries and protected areas is one of the best tools in managing aquatic resources. There are a number of sanctuaries and protected areas designated by the Federal and State governments (Table 5).

Artificial reefs and mangrove replanting

To mitigate factors causing resource over-exploitation and habitat loss and degradation, the government has long undertaken resource enhancement activities such as restocking and artificial reef programs.

a) Artificial reefs

Traditional artificial reefs of bamboo and coconut leaves started as early as the fishing industry in Malaysia. The Department of Fisheries first launched tire-made artificial reefs in 1975 in areas near Pulau Telor, Kedah (Zainuddin and Abdul-Razak 2000, Latun and Wong 1988, Omar et al 1991). Since then more than 40 sites of tire reefs have been installed around Peninsular Malaysia and Sarawak. This was followed by the use of other materials and designs such as sunken boats and concrete. Artificial reefs have proven to be effective and useful in Malaysia hence their development continues to be an important undertaking (Abdul-Razak and Ismail 1992, Wagiman et al 1994). Various materials and designs may be attempted in the future, taking into consideration successes reported by some authors (Baine and Heaps 1992, Collins et al 1992, Eggleston et al 1992, Jensen et al 1994(a), Jensen et al 1994(b), Snapier 1994).

b) Mangrove replanting

There are about 560,000 ha of mangrove forests in Malaysia. The Kerian and Kuala Sepetang mangrove reserves in Perak are good examples of properly managed mangroves where sustainable use and scheduled replanting are practiced. The recent tsunami incident that seriously hit neighbouring countries has prompted Malaysia to give special attention to mangrove replanting starting 2007 until 2010.

Stock enhancement/artificial restocking

Efforts to restock freshwater fishes and prawns were attempted as early as the 1980s. Approximately 30 species of these aquatic vertebrates have been included in the release programs. The most common species selected for restocking are given in Table 6.

The current problems regarding heavily depleted aquatic resources have prompted the government to look into this matter seriously. Stock enhancement will become another important tool that will dominate fisheries management in this country in the years to come.

National Restocking/Stock Enhancement Program

Species stocked

Freshwater species

Table 6 shows the species used for restocking in natural water bodies in Malaysia, of which the five most common species are the Javanese carp, Common carp, Giant freshwater prawn, Red tilapia and River catfish. The Red tilapia tops the list with a record of two million juveniles released in 2003. The Department of Fisheries plans to step up work on release programs for Kelah and Temoleh, after some success in artificial breeding (Ahmad-Ashar 1992).

Brackishwater and marine species

Restocking and enhancement for sea turtles and painted terrapin have been an on-going program for decades. No stock enhancement has been attempted for brackish-water and marine species because of the lack of breeding technology to date. Research is being carried out to develop and establish breeding technologies for sea cucumbers, to be followed by giant clams and seahorses.

Marking and tagging

Marking and tagging of fish have limited application in Malaysia. Passive Integrated Transponder (PIT) tags have been used in the country to mark mature females and F_2 arowana juveniles for export purposes.

Table 6. Culture-based fisheries and aquaranching in Malaysia.

Culture-based Fisheries	Aquaranching
Freshwater Fish in used mining pools – various species Freshwater lakes (man-made) – various species Freshwater fish in net-cages – various species Culture of red claw (*Cherax quadricarinatus)* in ponds	**Freshwater** Tilapia (*Oreochromis* spp.) Catfish (*Clarias* spp., *Pangasius* spp.) Freshwater prawn (*Macrobrachium rosenbergii)* Chinese major carps (bighead, grass and common) Indian carps (rohu, catla) Javanese carps Local cyprinids
Brackishwater Penaeid or marine prawn culture in trapping ponds Mussel culture (raft and pole methods Oyster culture (raft method) Marine finfish culture in net-cages Pen culture in lagoons	**Brackishwater** Cockles Mussels Grouper Oysters Mud crabs
Marine Cockles using on-bottom culture Mussel *(Perna viridis)* using raft and poles Oyster (*Crassostrea* spp.) using raft	**Marine** Cockle *(Anadara granosa)* Penaeid prawn *(Penaeus monodon)* Seabass *(Lates calcarifer)* Grouper *(Epinephelus* spp.) Snapper *(Lutjanus* spp.) Mussel *(Perna viridis)* Oyster *(Crassostrea* spp.) Seaweed *(Eucheuma, Gracilaria)*

Release strategies

Direct release of marine turtle and terrapin hatchlings has been practiced as this method simulates Mother Nature. For fishes, releases have been attempted to restore stocks in original habitats. Information on when, where and how best to release the juveniles should be determined through research.

Impact on catches

Appropriate studies have not been carried out to determine the impact of stock enhancement on the environment. Preliminary efforts to study the income and turtle related tourism and the impact of artificial reefs on the economy of traditional fishers are underway.

Monitoring

Monitoring the progress of stock enhancement activities is undertaken by the Department of Fisheries for selected freshwater species.

Government agencies, NGOs involved

Federal and State agencies involved in implementing restocking program collaborate with local universities insofar as research activities are concerned. The involvement of non-governmental organizations is concentrated on the conservation of freshwater species at two localities, namely, the Sungai Nenggiri Sanctuary in Gua Musang, Kelantan and the Tasek Bukit Merah Sanctuary in Taiping, Perak.

Co-management by local communities

One good example of the community-based resource management for freshwater species is the so-called *tagal* (closed) system in Sabah. Local communities that live near the rivers are given traditional rights to manage and exploit resources from selected rivers. The selected rivers (total of 174, to date) are closed for one or two years. The communities look after the rivers and they are allowed to fish only on selected days in a year. Those who illegally fish and pollute the rivers can be fined.

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Stock Enhancement Activities in the Union of Myanmar

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Introduction

The geography of the Union of Myanmar favors the existence of almost 700 species of marine and freshwater fauna. The resources are diverse and consist of indigenous, economically important commercial species, as well as ornamental species.

The fertile continental shelves, dense mangroves and coral beds along the coastal stretch are prime spawning and feeding grounds for a wide variety of species. Increasing demand for finfish, crustaceans and mollusks for food as well as for ornamental purposes has resulted in the over-exploitation of resources.

Endangered Species

In Myanmar, two freshwater fish species, Asian arowana *Scleropages formosus* and giant catfish *Pangasianodon gigas,* and two marine fish species, whale shark *Rhincodon typus* and seahorse *Hippocampus kuda* are currently listed in the Convention on International Trade of Endangered Species of Fauna and Flora (CITES) appendices.

Myanmar Wild Life Law

The following species are found in the list of protected species under the Myanmar Wild Life Law:

- Tubenose stickleback *Indostomous paradoxus*
- Carp *Osteobrama vigorsii*
- Butter catfish *Silonia silondia*
- Upside-down catfish *Mystus leucophasis*

Exploitation of endangered species is strictly prohibited hence, there are no recorded catches for these species.

Status of seed production technologies

Seed production in Myanmar is focused on freshwater fish – carps (breeding by hypo physation method), tilapia, and catfish. Seeds of freshwater fish are produced in millions for distribution to grow-out farms and for stock enhancement.

Aquatic Resources Management

Fisheries laws

Fisheries resources in Myanmar are important for livelihood and food security. Export earnings from the fisheries sector rank third after agriculture and forestry products. These resources are categorized into inland fisheries, coastal and marine fisheries, and aquaculture.

The Department of Fisheries (DOF) has enacted the following laws for fisheries management:

1. Freshwater Fisheries Law (1991)
2. Myanmar Marine Fisheries Law (1990), amended in 1993
3. Law relating to the fishing rights of foreign fishing vessels (1989), amended in 1993
4. Aquaculture Law (1989)

Freshwater Fisheries Law

The Law stipulates the following:

a) Further development of the fisheries
b) Prevention of the extinction of fish

c) Prevention of the destruction of freshwater fish habitats
d) Payment of duties and fees to the State
e) Management of fisheries in accordance with the Law.

Regarding the prohibitions in fisheries, the Law states that:

a) No one shall be allowed to do the following in any freshwater bodies of water:
   - Catching fish using explosives and toxic substances
   - Catching fish using prohibited implements and methods
   - Catching fish of prohibited size
b) No one shall construct, install or maintain obstructive dams, banks, or wire fences in freshwater fisheries without permission from the DOF.
c) No one shall be allowed to do the following within the boundary of creeks important to fisheries:
   - Cutting undergrowth or setting fire in fish habitats
   - Disrupting the flow of water
d) No one shall be allowed to cause disturbance to fish and other aquatic organisms, or cause pollution in waterways in leased or reserved fisheries areas, and contiguous creeks.

Moreover, the legislation also describes penalties for violations.

Myanmar Marine Fisheries Law

The Law includes prohibitions on the following:

a) No person shall engage in inshore and offshore fishery activities without a license.
b) No person shall keep explosives and toxic substances on board fishing vessels for use in fishing.
c) No person shall dispose of living aquatic organisms or any material into marine waters that would cause pollution or disturbance to fishes and other marine organisms.

The Law also mentions the duties and powers of fisheries inspectors.

Enforcement at different levels

The DOF is the only competent authority for fisheries in the country. The DOF in collaboration with CITES and other organizations like the World Conservation Union (IUCN) and WCS constantly evaluates the status of existence and survival of aquatic resources in nature.

Myanmar has undertaken efforts to protect rare fauna and flora, within the context of food security issues and sustainable livelihood of the people managing the aquatic resources. The DOF has conducted aquatic resource management by regulating the collection according to species, season, fishing grounds, and implements. In this regard, fisheries officers at the provincial, district and township levels are the key force in monitoring and exercising management in collaboration with local authorities and related departments.

For commercial purposes, one can obtain the right to utilize fishery resources, in the country by procuring a license. However, fishing for household consumption is exempted from such license.

Habitat protection

In collaboration with the Forestry, Agriculture and the Irrigation Departments, the DOF actively participates in the protection of habitat, spawning and feeding grounds of aquatic animals.

There are wildlife sanctuaries and protected areas in Myanmar managed by the Forestry Department. The same Department also undertakes mangrove protection and replanting.

Table 1. Number of fish seed stocked into the natural waters of Myanmar from 1990 to 2005.

Year	No. of fish seed stocked (x 10^3)
1990-1991	3.25
1991-1992	6.00
1992-1993	3.80
1993-1994	7.25
1994-1995	64.70
1995-1996	124.46
1996-1997	50.00
1997-1998	33.00
1998-1999	65.37
1999-2000	56.98
2000-2001	85.80
2001-2002	92.80
2002-2003	134.30
2003-2004	218.60
2004-2005	236.50

Stock Enhancement Programs

The State's vision is to assist the national economy by promoting livelihood programs for rural people through the development of the fisheries sector. To achieve such goal, one of the major activities is to undertake a stock enhancement program which has been implemented since 1983. The DOF subsidizes the annual seeding of freshwater fish and prawns into natural waters.

Species stocked

Species used in seeding include common carp, tilapia, rohu, catla, and featherbacks fish, freshwater prawn *Macrobrachium* and tiger shrimp *Penaeus monodon*. Activities include annual stocking of seeds in the Ayeyarwaddy River and its tributaries, lakes, reservoirs, dams and other bodies of water. The annual seeding program has recorded millions of fish seed stocked from 1990 to the present (Table 1).

Impact on catches

Among the species listed in the CITES, the Asian Arowana has commercial value as ornamental fish. Arowana are found in the stream at Tanintharyi Division. The giant catfish *P. gigas* inhabit the upper Ayeyarwaddy River and its tributaries in the north. However, these species are not exploited for commercial purpose.

The whale shark is not a popular food fish and it is not a target species by the local fishers. The anchovy surrounding nets in the Rakhine coastal areas often accidentally caught sharks but usually released back into the sea. Since early 2000, the increasing price of shark meat due to export demand has been attracting local fishers to target this animal. In this regard, the DOF enhances activities in educating the fishers to safeguard endangered species and takes actions in accordance to Fisheries Laws to those who violate.

H. kuda and other seahorse species are found in all coastal areas in Myanmar. Recently, people in coastal areas became interested in seahorse because it commands an attractive price. Seahorse is used by the Chinese as traditional medicine. These animals are caught using the anchovy surrounding nets.

Among the species protected under the Myanmar Wildlife Law are tubenose *I. paradoxus* and upside-down catfish *M. lucophasis* which are valued as freshwater ornamental fish. *I. paradoxus* is found in Indaw Gyi Lake at Kachin State in northern Myanmar. The upside down catfish inhabits rivers and streams in lower and upper Myanmar. The sustainability of this species in natural habitat has been threatened since the demand for export is increasing. In this regard, the DOF has controlled its export.

The carp *O. virgosii* and butter catfish *S. silondia* are popular food fish. *S. silondia* is one of the expensive food fish in Myanmar. They thrive in rivers and large streams of upper Myanmar. Since the late 1990s, the catch has gradually declined and scarcely seen in local markets. This may be due to overexploitation or destruction of their habitat. Currently, the DOF has undertaken efforts to conserve these species through Myanmar Wild Life Law.

Monitoring

Stock enhancement activities, protection and conservation are mainly monitored by the fisheries inspectors in collaboration with local management authorities, the Forestry Department and the police force.

The DOF is the only competent authority to monitor and conduct fisheries related activities. The Myanmar Fisheries Federation is the most competent NGO in fisheries supporting the activities of the DOF.

Co-management by local communities

Attempts have been made to increase awareness in fisheries co-management to sustain resources through responsible fisheries and aquaculture practices. The activities are implemented with transparency. The stock enhancement and conservation activities are participatory with support and co-management from stakeholders.

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Status of Threatened Species and Stock Enhancement Activities in the Philippine Fisheries

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Introduction

The Philippine archipelago, with 7,100 islands endowed with freshwater, estuarine and marine resources, provides habitats to more than a million species of flora and fauna. Many of these species are commercial commodities for human consumption. Biological, geographical, population, and ecological assessments as to whether these species are over-exploited, near extinction, rare, endangered or threatened, are scarce. This paper reviews the country's threatened fishery resources (excluding exotic species) and describes the existing conservation and rehabilitation efforts, and recommends resource management interventions.

The Philippines is participant of the Convention on the International Trade of Endangered Species of Fauna and Flora (CITES), sharing lists of species common to each country which may be classified as threatened or endangered. Although the country has not formally adopted the categories and guidelines of the International Union for the Conservation of Nature (IUCN) (Francisco and Sievert 2004), it has implemented globally accepted measures for marine ecosystem conservation, particularly the establishment of Marine Protected Areas (MPAs).

Despite available listings to date, there is no systematic inventory or monitoring report which classifies whether flora and fauna in Philippine waters are extinct, endangered or threatened, over-exploited or totally depleted. As to what basis and by whose authority species are declared rare, endangered, extinct, or threatened remains a grey area.

Endangered Species

The Philippine listings of fisheries related species perceived to be extinct, rare, threatened and endangered as covered under the CITES, IUCN and the Bureau of Fisheries and Aquatic Resources (BFAR)-Fisheries Administrative Order (FAO) No. 208 listed commodities in freshwater (Table 1) and marine environments (Tables 2 and 3) are presented as follows:

The listings of freshwater fisheries resources constitute mostly finfishes that are all, except for one, found in the CITES list, the rest under the IUCN red lists and none in the BFAR list. Majority of the listed species are also specific to some areas like Lanao Lake, few in the RINCONADA lakes of Bicol and scarce in some other minor lakes where they are found to be endemic. Most of the indigenous cyprinid species are of commercial value to the locality and are the main source of fish protein in the daily life of the fisherfolk.

The listings of marine finfishes constitute mostly sharks and seahorses which are all, except for one, found in the CITES list, the rest under the IUCN Red List and none in the BFAR-FAO list. Although BFAR listed 20 species of whales and dolphins under its FAO 208, marine mammals are not included in this report. Most of the indigenous shark species are becoming rare and extinct due to the rampant shark

Table 1. List of endangered, rare and extinct freshwater fish species in the Philippines.

Scientific name	English name	Local name	Habitat/ distribution	Listings	
				IUCN	CITES
Spratellicypris palata	Lanao carp	Palata	Lake Lanao endemic	_/	
Ospatulus truncatulus	Lanao carp	Bitungo	Lake Lanao endemic	_/	
Ospatulus palaemophagus	Lanao carp		Lake Lanao endemic	_/	
Mandibularca resinus	Lanao carp	Bagangan	Lake Lanao endemic	_/	
Puntius sirang	Lanao carp	Sirang	Lake Lanao endemic	_/	
Puntius tras	Lanao carp	Tras	Lake Lanao endemic	_/	
Puntius tumba	Lanao carp	Tumba	Lake Lanao endemic	_/	
Puntius amarus	Lanao carp	Pait	Lake Lanao endemic	_/	
Puntius baoulan	Lanao carp	Baolan	Lake Lanao endemic	_/	
Puntius katolo	Lanao carp	Katolo	Lake Lanao endemic	_/	
Puntius clemensi	Lanao carp	Bagangan	Lake Lanao endemic	_/	
Puntius disa	Lanao carp	Disa	Lake Lanao endemic	_/	
Puntius flavifuscus	Lanao carp	Katapa-tapa	Lake Lanao endemic	_/	
Puntius lanaoensis	Lanao carp	Kandar	Lake Lanao endemic	_/	
Puntius lindog	Lanao carp	Lindog	Lake Lanao endemic	_/	
Puntius manalak	Lanao carp	Manalak	Lake Lanao endemic	_/	
Puntius herrei	Lanao carp		Lake Lanao endemic	_/	
Puntius pachycheilus	Lanao carp		Lake Lanao endemic	_/	
Puntius manguaoensis	Palawan carp		Lake Manguao endemic	_/	
Puntius cataractae			Mindanao	_/	
Puntius hemictenus	Naujan carp		Lake Naujan endemic	_/	
Hampala lopezi			Busuanga	_/	
Stiphodon surrufus	Goby		Leyte endemic	_/	
Sicyopus auxilimentus	Goby		Leyte endemic	_/	
Mistichthys luzonensis	Goby	Sinarapan	Lake Buhi endemic	_/	
Redigobius bikolanus	Bigmouth goby	Biya	Endemic in RINCONADA Lakes of Bicol region	_/	
Pandaka pygmaea	Dwarf pygmy goby	Bia	Malabon and Mindanao		_/

Sources: http://www.cites.org.2004. Listings of Philippine fisheries endangered species
http://www.fishbase.org.2004. Summary of Philippine fisheries species in red list status
http://www.iucn.org.2004. Red list of endangered fisheries species in the Philippines
BFAR-FAO 208 (2001)

fisheries with the rising demand of shark fins smuggled or exported abroad.

These marine finfishes are distributed in coastal waters.

The listings of marine gastropods, mollusks, crustaceans and echinoderms are all found in the BFAR-FAO listings as Rare, Threatened and Endangered, while few and selective under the CITES and IUCN lists. Accordingly, these are the most common marine resource commodities that are over-exploited, gleaned and gathered illegally, and frequently exported or smuggled out of the country by unscrupulous traders.

Why rare, threatened and endangered?

The BFAR is mandated by law (Republic Act or RA 8550) to identify and manage species that are found to be rare, threatened and endangered. This prompted the issuance of FAO No. 208 classifying 26 gastropods and two bivalve species under the rare category; three gastropods and one crab as threatened species; 20 dolphins and whales as endangered species, including seven species of clams and one sea snake. These categories are defined under FAO No. 208 as follows:

rare - fishery or aquatic resources with small world populations that are not endangered or presently vulnerable

threatened - a general term which may be used to describe a fishery or aquatic species whose population is endangered, vulnerable or rare

endangered - refers to the species, subspecies, including the eggs, offspring, parts and derivatives of plants and animals as listed in the CITES Appendices.

The BFAR listings are based on results of field research conducted until 2001. They are shorter than the CITES list as of 2004 because there are no recent studies. At closer look, the CITES list only covers species that are traded and marketed but not those without market value, while IUCN gives emphasis to the preservation and conservation of the species heritage of the planet, which is the prime concern of the Department of Environment and Natural Resources (DENR).

Status of seed production technology

Many species listed by the IUCN, CITES and BFAR have no hatchery/seed production activities in the Philippines. However, some of the species that are being propagated on an experimental scale are the giant clams *Tridacna* spp., sea cucumbers and sea urchins as pioneered by the University of the Philipppines-Marine Science Institute (UP-MSI); abalone and top shell *Trochus* spp., seahorse and groupers by the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD), and the native catfish, lobed-lip river mullet and weather loach currently being undertaken by BFAR.

Aquatic Resource Management

Resource management measures in the Philippines are supported by management programs, protected by policy rules and regulations, and implemented by many key players and stakeholders. But who plays what are the issues described in the following sections.

Fishery and other laws/regulations

There are three policy making bodies involved in the formulation and implementation of laws pertaining to aquatic resources management, namely: the DENR, Department of Agriculture Bureau of Fisheries and Aquatic Resources or DA-BFAR and the Local Government Units (LGUs). The following particular laws apply:

Table 2. List of endangered, rare and extinct marine fish species in the Philippines.

Scientific name	English name	Local name	Listings	
			IUCN	CITES
Aetomylaeus nichofii	Banded eagle ray		_/	
Urogymnus asperrimus	Porcupine ray	Pagi	_/	
Taeniura lymma	Blue-spotted sting ray	Pagi	_/	
Aetobatus narinari	Spotted eagle Ray	Pagi	_/	
Manta birostris	Manta ray	Pagi	_/	
Rhina ancylostoma	Bowmouth guitarfish	Pagi	_/	
Rhynchobatus australiae	White-spotted wedgefish	Pating sudsod	_/	
Rhynchobatus djiddensis	whitespot giant uitarfish	-do-	_/	
Pristis pectinata	Wide sawfish		_/	
Anoxypristis cuspidata	Knifetooth seafish	-do-	_/	
Carcharodon carcharias	Great white shark	Pating	_/	_/
Apristurus herklotsi	Longfin catshark	Pating	_/	
Apisturus platyrhynchus	Spatulasnout catshark	Pating	_/	
Atelomycterus marmoratus	Coral catshark	Pating	_/	
Carcharhinus amblyrhynchoids	Graceful shark	Pating	_/	
Carcharhinus borneensis	Borneo shark	Pating	_/	
Carcharhinus brevipinna	Spinner shark	Pating	_/	
Carcharhinus dussumieri	Widemouth blackspot shark	Pating	_/	
Carcharhinus hemiodon	Pondicherry shark	Pating	_/	
Carcharhinus leucas	Bull shark	Pating	_/	
Carcharhinus limbatus	Blacktip shark	Pating	_/	
Carcharhinus longimanus	Oceanic whitetip shark	Pating	_/	
Carcharhinus melanopterus	Black-tip reef shark	Pating	_/	
Carcharhinus sealei	Blackspot shark	Pating	_/	
Carcharias taurus	Sand tiger shark	Pating	_/	
Centrophorus isodon	Black gulper shark	Pating	_/	
Centrophorus moluccensis	Endeavour dogfish	Pating	_/	
Centrophorus squamosus	Deepwater spiny dogfish	Pating	_/	
Centroscyllium kamoharai	Jelly shark	Pating	_/	
Chiloscyllium griseum	Grey bamboo shark	Pating	_/	
Chiloscyllium indicum	Frog shark	Pating	_/	
Chiloscyllium punctatum	Brown-spotted catshark	Pating	_/	
Galeocerdo cuvier	Tiger shark	Pating	_/	
Eusphyra blochii	Slender hammerhead	Pating	_/	
Hemipristis elongata	Fossil shark	Pating	_/	
Hemitriakis leucoperiptera	Whitefin topeshark	Pating	_/	
Hexanchus griseus	Bluntnose sixgill shark	Pating	_/	
Megachasma pelagios	Megamouth shark	Pating	_/	
Nebrius ferrugineus	Tawny nurse shark	Pating	_/	
Prionace glauca	Blue shark	Pating	_/	
Sphyrna lewini	Scalloped hammerhead	Pating	_/	
Sphyrna mokarran	Great hammerhead	Pating	_/	
Sphyrna zygaena	Smooth hammerhead	Pating	_/	
Triaenodon obesus	White-tip reef shark	Pating	_/	
Stegostoma fasciatum	Leopard shark	Pating	_/	
Squalus acanthias	Piked dogfish	Pating sudsud	_/	

Table 2 (continued from p. 124)

Scientific name	English name	Local name	Listings	
			IUCN	CITES
Squalus mitsukurii	Green-eye spurdog	Pating sudsud	_/	
Isurus oxyrinchus	Shortfin mako shark	Pating sudsud	_/	
Hippocampus barbouri	Barbour's seahorse	Kabayong dagat	_/	
Hippocampus bargibanti	Pygmy seahorse	Koro-kabayo	_/	
Hippocampus comes	Tigertail seahorse	Koro-kabayo	_/	
Hippocampus kelloggi	Great seahorse	Koro-kabayo	_/	
Hippocampus kuda	Spotted seahorse	Koro-kabayo	_/	
Hippocampus spinosissimus	Hedgehog seahorse	Kabayong dagat	_/	
Hippocampus trimaculatus	Longnose sea horse	Koro-kabayo	_/	
Pegasus volitans	Long-tail sea moth		_/	
Torquigener brevipinnis	Pufferfish	Botete	_/	

Sources: http://www.cites.org.2004. Listings of Philippine fisheries endangered species http://www.fishbase.org.2004. Summary of Philippine fisheries species in Red List status http://www.iucn.org.2004. Red list of endangered fisheries species in the Philippines BFAR-FAO 208 (2001)

- RA 8550, Article III - Operational Standards and Procedures Sec.1: Identification and management of rare, threatened or endangered species (except crocodiles, turtles and dugong) is bestowed upon BFAR
- RA 8550, Article IV - Mapping, Charting and Identification of Certain Areas Sec. 4: Fishery refuge, reserves and sanctuaries bestowed upon BFAR to establish criteria and procedures except in National Integrated Protected Area System (NIPAS)

Although BFAR is tasked to implement most of the provisions in the Revised Fisheries Code (RA 8550), the DENR and LGUs also have specific roles pertaining to management of aquatic resources. The NIPAS Act implemented by the DENR has provisions affecting coastal resource activities in fisheries that is, in fact the concern of the LGUs as administrators of local resources.

Enforcement

The following government agencies are responsible for implementing fishery regulations:

- DA-BFAR - lead agency in formulating regulatory mechanisms directly related to fisheries, particularly outside municipal waters
- DENR - regulates foreshore and shoreline areas and mandated to conserve and protect coastal/marine environment jointly with the LGUs
- Department of Transportation and Communication (DOTC) - regulates commercial fishing vessel licenses and enforces anti-pollution measures in shipping through the Philippine Coast Guard (PCG) and the Maritime Industry Authority (MARINA)
- LGUs - share responsibility with the national government in maintaining ecological balance and enforcing fishery laws pertaining to municipal waters and mangrove conservation; and formulation and enforcement of local ordinances based on national laws and regulations.

Territorial Use Rights (TURFs)

The concept of TURFs as applied to the present management of aquatic resources in the Philippines is also governed by basic national laws. The Local Government Code (RA 7140) assigns to the municipal governments the responsibility of creating and implementing guidelines for local fisheries, granting duly registered organizations and

Table 3. List of endangered, rare and extinct marine bivalves, gastropods, cephalopods and echinoderm species in the Philippines.

Scientific name	English name	Local name	Distribution	Listings		
				IUCN	CITES	FAO 208
Amusium obliteratum	Smuggled moon scallop		Philippine Coastal Waters			_/ R
Eufistulana mumia	Club-shaped boring clam		-do-			_/ R
Hippopus hippopus	Bear paw giant clam	Kabibe	-do-	_/	_/	_/ E
Hippopus porcellanus	Porcelain giant clam	Kabibe	-do-	_/		_/ E
Pholas orientalis	Angel wing clam	Diwal-do-	Endemic in Capiz, Iloilo, Negros	_/		_/ T
Tridacna gigas [a]	Giant clam	Taclobo	Philippine marine waters	_/	_/	_/ E
Tridacna maxima	Small giant clam		-do-	_/		_/ E
Tridacna squamosa	Scaly giant clam		-do-	_/	_/	_/ E
Tridacna derasa	Giant clam		-do-		_/	_/ E
Tridacna crocea	Southern giant clam		-do-	_/	_/	_/ E
Trochus niloticus [a]	Trochus shell		-do-	_/	_/	_/ T
Bolma girgyllus	Girgyllus star shell		-do-			_/ R
Clypeomorus aduncus	Bent cerith		-do-			_/ R
Recluzea lutea	Recluzia snail		-do-			_/ R
Separatista blainvilliana	True separatista		-do-			_/ R
Malluvium lissus	Deep sea cap		-do-			_/ R
Strombus thirsites	Thersite stromb		-do-			_/ R
Varicospira crispata	Network beak shell		-do-			_/ R
Tibia martini	Martini's tibia		-do-			_/ R
Cypraea childreni	Children's cowrie		-do-			_/ R
Cyprae beckii	Beck's cowrie		-do-			_/ R
Cyprae guttata	Great spotted cowrie		-do-			_/ R
Cyprae porteri	Porter's cowrie		-do-			_/ R
Cyprae teramachii	Teramachi's cowrie		-do-			_/ R
Cyprae martini	Martini's cowrie		-do-			_/ R
Cyprae saulae	Saul's cowrie		-do-			_/ R
Cyprae katsuae	Katsue's cowrie		-do-			_/ R
Cyprae leucodon	White toothed cowrie		-do-			_/ R
Cyprae aurantium	Golden cowrie		-do-			_/ T
Cyprae valentia	Prince cowrie		-do-	_/		
Phenacovolva dancei	Dance volva	Tatus	Quezon Islets, Batan Is.	_/	_/	_/ T
Cypraeacassis rufa	Bullmouth helmet	Trepang, Balat	-do-		_/	
Phalium coronadoi wyvillei	Wyville's bonnet					_/ R
Phalium glabratum	Glabratum smooth bonnet					_/ R
Morum kurzi	Kurzi's morum					_/ R
Morum grande	Giant morum					_/ R
Morum watsoni	Watson's morum					_/ R

Legend: [a] Hatchery technology available; R- Rare; T- Threatened; E- Endangered
Sources: http://www.cites.org.2004. Listings of Philippine fisheries endangered species; http://www.fishbase.org.2004. Summary of Philippine fisheries species in Red List status; http://www.iucn.org.2004. Red list of endangered fisheries species in the Philippines; BFAR-FAO 208 (2001)

cooperatives of marginalized fishermen preferential rights to fishery privileges and setting municipal fisheries 15 km from the shoreline. The Fisheries Code (RA 8550) on the other hand, implies the return of resource management from national agencies to municipal governments and gives preferential use rights in municipal waters to municipal fisherfolk.

Habitat protection and rehabilitation

The Resource Enhancement Projects (REPs), which combine fish sanctuary, fisheries reserve, and mangrove rehabilitation, are pioneering activities of the Fisheries Resource Management Program (FRMP) of DA-BFAR. As of September 2003, 215 REPs (123 fish sanctuaries and 92 mangrove projects) were established in 18 FRMP bay areas throughout the country (FRMP 2003).

Sanctuaries and protected areas

Marine Protected Areas (MPAs), also known as "no-take zones", sanctuaries, reserves, harvest refugia, and marine parks, are marine areas protected by law or other mechanism from one or more activities. There are 459 known MPAs nationwide (White et al 2004), probably the most numerous in Southeast Asia, but most are referred to as "paper parks" due to lack of sustainable management strategies. Nonetheless, there are well established, successful parks in the Philippines such as the Hundred Islands National Park. It was created by Presidential Proclamation in 1970 followed by PD 564 establishing the first national park in the Philippines jointly managed by the Philippine Tourism Authority and the LGU of Alaminos, Pangasinan.

This was followed by the Sumilon Marine Reserve (1974) and Apo Island Marine Reserve (1985), the first fishery reserves established in the country. The United Nations Educational, Scientific and Cultural Organisation (UNESCO) declared Puerto Galera a Biosphere Reserve in 1977, and the Tubattaha Reef a Biosphere Reserve in 1990 and World Heritage Site in 1993. Despite the good start and all-out efforts of the government, management levels of Philippine MPAs are considered "low" at 16-38% (Aliño et al 2004). Therefore, the establishment of non-government organizations e.g., the Pambansang Alyansa ng Maliliit na Mangingisda at Komunidad sa Nangangalaga ng Karagatan at Sanktuaryo sa Pilipinas (PAMANA) and Haring Ibon (HARIBON) Foundation, in the late 1980s has been essential to the information-education campaign to sustain the management of MPAs. To evaluate the effectivity and efficiency of MPAs, a Management Rating System was formulated in 2001 by the Coastal Conservation and Education Foundation.

Artificial reefs

Artificial Reefs are structures installed at the sea bottom that serve as shelters, feeding and breeding areas of fish, whereas Fish Aggregating Devices (FADs, locally known as *payaw*) are structures anchored at the surface or drifting at the mid-water levels which attract and aggregate fish. Originally set up to protect fish communities, FADs instead encouraged overfishing often with the use of dynamite, cyanide, and unregulated mesh size nets (Babaran 2004).

National Restocking or Stock Enhancement Program

"National Stock Enhancement" or "Restocking Program" in the Philippines does not virtually exist as a matter of written policy, yet it has recently been practiced and implemented independently by concerned institutions and fisheries agencies according to their program mandates. BFAR, for example, over the years since its existence as the Philippine Fisheries Commission, has carried out an annual "Fish Dispersal Program" in Laguna de Bay and major inland lakes (Villadolid 1965). This was carried on through tradition by reseeding lakes and inland waters on special occasions during annual Fish Conservation Week celebrations or when a President of the state visits a particular inland lake area as part of a ceremonial activity. The implications, however, may result in negative diversities in the reseeded areas since no regular follow-up nor monitoring has been done to check whether the reseeded areas have been overstocked or have been critically depleted of their resources. This is especially true since there have been no available biological productivity and carrying capacity studies, stock recruitment and Catch per Unit Effort (CPUE) data. It was not until 1980 that successful hatchery breakthroughs in the Philippines were reported and stock enhancement activities in marine waters as initiated by UP-MSI (especially the giant clam mariculture technology) were undertaken (Juinio-Menez 2004). This was followed by UP-MSI's sea urchin hatchery production in the 1990s, after the collapse of the sea urchin population in Bolinao. Moreover, UP-MSI pioneered in sea cucumber, top shell and abalone seedstock production in 2002 and recently, SEAFDEC/AQD also initiated the culture and stock enhancement of abalone and top shells.

Impact on catches

To determine the impact of stock enhancement on existing aquatic resources, the following factors should be given due attention:

- Loss of genetic diversity – negative impact on stock enhancement;
- Unregulated stock enhancement – may lead to displacement of other species in the natural environment
- Information needed to assess the potential benefits of restocking (Bell and Garces 2004):
  a) Stock delineation or the size and distribution of stocks supporting a particular fishery to enable the development of an appropriate stock enhancement program
  b) Stock assessment or the status of the population should be identified
  c) Capacity of hatcheries to produce sufficient juveniles
- Other components of restocking program
  a) Hatchery protocols to maintain the genetic diversity of the stock
  b) Requirement of released juveniles
  c) Quarantine procedures
  d) Management measures to maximize benefits and determine the contribution of restocking to recovery
- Other components of a responsible stock enhancement program
  a) Maintaining sufficient spawning biomass for replenishment
  b) Rotational fishing
  c) Integration with aquaculture
  d) Artificial habitats
  e) Removal of predators

Monitoring

Monitoring, Control and Surveillance (MCS) under the FRMP integrates various elements of fisheries resource management into a three-tiered system of data collection (monitoring), legislation (control) and enforcement (surveillance). The MCS Investment plan includes setting up of one national and eight regional MCS coordination centers.

Co-management by local communities/stakeholders

Since LGU funding is not always enough, Eisma (2004) suggested the following list of possible funding mechanisms to initiate co-management efforts:

a) Amend specific provisions of the Local Government Code (LGC) to make Coastal Resource Management (CRM) a basic service similar to health, agriculture, etc.
b) Include municipal waters in the computation for sharing in Internal Revenue Allocations (IRA)

c) Develop guidelines for use of the Environment Guarantee Fund to include CRM
d) Appropriate special funds for CRM programs for LGUs in the Government Annual Appropriations (GAA)
e) Review/revise guidelines to include use of 20% development fund for CRM
f) Expand the menu of projects in the Rural-Urban development fund for CRM
g) Include through an amendment, CRM as a priority area in coming up with the Annual Investment Plan
h) Legislate through an ordinance, a special assessment tax or fee for a local CRM fund similar to the Special Education Fund as collected via the real property tax; and
i) Tap the private sector and/or NGOs through their vested interests as a source of funds and donors of equipment, honoraria for "Bantay Dagat" (or deputized fisherfolks as law enforcers in charge of patrolling the municipal waters and apprehending illegal fishers).

Summary, Conclusions and Recommendations

The Philippines is endowed with a diversity of marine resources valuable to the economic livelihood of the fishing community. The demand to supply the domestic and foreign market has caused the overexploitation and depletion of these aquatic resources. Conservation, management, preservation and the wise utilization of these marine species are the prime concern of the government. However, lapses in the regulations, policies and implementation of existing laws are still intricacies which require sound governance to systematic and scientific approaches as well as intervention involving the resource users and policy makers.

International agreements which relate to the classification of these species as to their degrees of exploitation, are governed by CITES which is compulsory, and IUCN, though non-obligatory. But in the domestic fisheries trade and industry, specific regulations are set forth in FAO 208 which prohibits the taking, catching, or gathering of species that are categorized as rare, endangered and threatened. Yet there is still a need for the government to collaborate with the international regulatory bodies in assessing the biological, geographic, ecological population of these species to come up with a systematic inventory, monitoring report and updating as to which species are to be classified as over-exploited, in near extinction, rare, endangered or threatened.

The Philippines employs various aquatic resource management programs and has also formulated numerous laws, rules and regulations towards conservation, rehabilitation, enhancement and management as a whole, but most of these are focused on the establishment of MPAs, artificial reefs, sanctuaries, reserves and mangrove habitat protection. Unfortunately, none of these laws has addressed fish seed stock enhancement in fisheries. There are but few independently implemented laws on pilot-test cases either under research, demonstration or on program/project-based interventions by concerned agencies and institutions.

With the establishment and commercialization of hatchery technologies, it is high time that a sound policy on fisheries National Stock Enhancement and Reseeding Program is implemented. A holistic, unified and harmonized program by the government where concerted efforts of concerned agencies, institutions, LGUs and stakeholders are bound into one systematic initiative on how, where and when restocking or reseeding interventions have to be made.

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Thailand's Concerns in Endangered Species and Stock Enhancement

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Introduction

Thailand is situated in the tropical zone, and has abundant freshwater coastal and marine resources. Thai fishermen catch fish for family consumption and for trade. The problem of endangered aquatic species in Thailand is caused mainly by the lack of tools for proper fisheries resource management and the limited breeding and aquaculture technologies for some of the threatened species.

Endangered Species

Thailand is a member of the Convention on the International Trade of Endangered Species of Fauna and Flora (CITES) and it has regulations to control the trade of endangered species. The endangered species of major concern in Thailand are listed in Tables 1 and 2.

Status of seed production technology

The Thai Department of Fisheries is breeding some of these endangered species under the "Rehabilitation of Thai Local Fishes and Aquatic Animals Project". Some of these species are bred for restocking in the wild. Table 3 shows the list of some of the endangered species propagated by the Department of Fisheries.

Aquatic Resource Management

Fishery laws and regulations

There are several laws that have been adopted to regulate the import, export and sale of endangered species. Likewise, there are also laws that protect species from various forms of inhumane treatment including illegal capture and killing.

Fishery Act, B.E. 2490 (1947)

1. Fishing is not allowed in the conservation area.
2. Disposal of toxic substances or pollutants into public water systems is not allowed.
3. Electric current or dynamite cannot be used for fishing.
4. Some fishing gears are prohibited during breeding season.

Importation Law, Decree B.E. 2547 (2004)

This law prevents the entry of diseases into Thailand which are brought in by exotic or imported fish species. Some fish species are not allowed for importation.

Prohibition of Imported Dangerous Species Decree B.E. 2530 (1987)

This decree prevents the importation and aquaculture of dangerous (invasive) species.

Wildlife Preservation and Protection Act, B.E. 2535 (1992)

This Act provides for the additional protection of wild animals including aquatic fauna. It is illegal to hunt, sell, buy or keep these wild animals or any of their parts or products (Sangchuen 2004, Fish Inspection Trade Section 2004).

Table 1. List of endangered freshwater species.

English name	Scientific name	Remark
Vertebrates		
Bonytongue	*Scleropages formosus*	CITES
Freshwater batfish	*Oreoglanis siamensis*	CITES
Siamese tiger fish	*Datnioides microlepis*	CITES
Ladderback loach/ Dwarf loach	*Botia sidthimunki*	IUCN
Indo china featherback	*Chitala blanci*	IUCN
Giant pangasius	*Pangasius sanitwongsei*	IUCN
Isok barb	*Probarbus jullieni*	IUCN
Laotian shad	*Tenualosa thibaudeaui*	IUCN
Giant barb	*Catlocarpio siamensis*	NC
Redtailed black shark	*Epalzeorhynchos bicolor*	NC
Catfish	*Clarias nieuhoffi*	NC
Indonesian featherback	*Chitala lopis*	NC
Carp	*Albulichthys albuloides*	NC
Carp	*Macrochirichthys macrochirus*	NC
Thicklip barb	*Probarbus labeamajor*	NC
Thinlip barb	*Probarbus labeaminor*	NC
Rasbora	*Rasbora somphongsi*	NC
	Ceratoglanis scleronema	NC
Catfish	*Kryptopterus limpok*	NC
	Ompok eugeneiatus	NC
	Wallago leeri	NC
	Coius undecimradiatus	NC
Freshwater ray	*Himantura laoensis*	NC
Bleeker's whipray	*Himantura bleekeri*	NC
Freshwater whipray	*Himantura chaophraya*	NC
Sharpnose stingray	*Himantura gerrardi*	NC
Freshwater ray ?	*Himantura krempfi*	NC
White-rimmed stingray	*Himantura signifer*	NC
Honeycomb stingray	*Himantura uarnak*	NC
Daggertooth pike conger	*Muraenesox cinereus*	NC
Whitefin wolf-herring	*Chirocentrus nudus*	NC
Bornean grenadier anchovy	*Coilia borneensis*	NC
Goldspotted grenadier anchovy	*Coilia dussumieri*	NC
Sabretoothed thryssa	*Lycothrissa crocodilus*	NC
Lindman' grenadier anchovy	*Coilia lindmani*	NC
Lowgjaw grenadier anchovy	*Coilia macrognathus*	NC
Dusky-hairfin anchovy	*Setipinna melanochir*	NC
	Setipinna waitei	NC
	Pellona filigera	NC
Raconda	*Raconda russeliana*	NC
	Barilius ornatus	NC
Dwarf rasbora	*Boraras maculatus*	NC
	Boraras micros	NC
	Boraras urophthalmoides	NC
Leaping barb	*Chela caeruleostigmata*	NC
Indian glass barb	*Chela laubuca*	NC
	Cirrhinus microlepis	NC

Table 1 (continued from p. 132)

English name	Scientific name	Remark
Hora danio	*Danio shanensis*	NC
	Discherodontus ashmeadi	NC
	Discherodontus schroeden	NC
Hoven's carp	*Leptobarbus hoeveni*	NC
	Mekongina erythrospila	NC
	Oxygaster maculicauda	NC
	Poropuntius speleops	NC
	Puntioplites bulu	NC
	Rasbora agilis	NC
	Rasbora bankanensis	NC
Harlequin rasbora	*Rasbora heteromorpha*	NC
Glowlight rasbora	*Rasbora pauciperforata*	NC
Sun loach	*Botia eos*	NC
	Botia longidorsalis	NC
	Botia splendida	NC
	Ellopostoma megalomycter	NC
	Homaloptera thamicola	NC
	Nemacheilus trogocataractus	NC
	Schistura jarutanini	NC
	Schistura oedipus	NC
	Vaillantella maassi	NC
	Bagrichthys macracanthus	NC
	Heterobagrus bocourti	NC
	Leiocassis poecilopterus	NC
	Leiocassis stenomus	NC
	Olyra longicaudata	NC
	Krytopterus apogon	NC
Glass catfish	*Krytopterus bicirrhis*	NC
	Krytopterus hexapterus	NC
	Ompok hypophthalmus	NC
	Silurichthys hasseltii	NC
	Silurichthys schneideri	NC
	Silurichthys leucopodus	NC
	Silurichthys phaiosoma	NC
	Silurichthys cochinchinensis	NC
	Akysis armatus	NC
	Akysis leucorhynchus	NC
	Akysis macronema	NC
	Akysis maculipinnis	NC
	Akysis pictus	NC
	Parakysis verrucosus	NC
Angler catfish	*Chaca bankanensis*	NC
Walking catfish	*Clarias batrachus*	NC
	Clarias leiacanthus	NC
	Prophagorus cataractus	NC
	Prophagorus nieuhofi	NC
Stinging catfish	*Heteropneustes fossilis*	NC
	Arias leiotetocephalus	NC

Table 1 (continued from p. 133)

English name	Scientific name	Remark
Beardless sea catfish	*Batrachocephalus mino*	NC
	Hemiarias stormi	NC
	Hemipimelodus borneensis	NC
	Hemipimelodus siamensis	NC
	Ketengus typus	NC
Giant catfish	*Arius thalassinus*	NC
	Neostethus bicornis	NC
	Neostethus lankesteri	NC
	Neostethus siamensis	NC
	Phenacostethus posthon	NC
Smith's priapium fish	*Phenacostethus smithi*	NC
	Hemirhamphodon pogonognathus	NC
	Zenarchopterus dunckeri	NC
	Zenarchopterus pappenheimi	NC
	Doryichthys martensii	NC
Spotted seahorse	*Hippocampus kuda*	NC
Pipe fish	*Indostomus paradoxus*	NC
Fire eel	*Mastacembelus erythrotaenia*	NC
Orange-spotted grouper	*Epinephelus coioides*	NC
Giant grouper	*Epinephelus lanceolatus*	NC
Atlantic tripletail	*Lobotes surinamensis*	NC
	Plectorhinchus haetodontoides	NC
Flagfin prawn goby	*Mahidolia mystacina*	NC
	Mahidolia normani	NC
	Odontobutis aurarmus	NC
	Mugilogobius rambaiae	NC
Silver pomfret	*Pampus argenteus*	NC
Chinese silver pomfret	*Pampus chinensis*	NC
Pikehead	*Luciocephalus pulcher*	NC
Malay combtail	*Belontia hasselti*	NC
	Parosphromenus paludicola	NC
Pearl gourami	*Trichogaster leerii*	NC
	Psettodes erumei	NC
	Chonerhinus naritus	NC
	Tetraodon suvatti	NC
Invertebrates		
Panda crab	*Phricotelphusa sirindhorn*	CITES
Pigal crab	*Demanietta sirikit*	CITES
Mealy crab	*Thaipotamon chulabhorn*	CITES

CITES – The Convention of International Trade in Endangered Species Fauna and Flora
IUCN – International Union for the Conservation of Nature
NC – National Concern

Table 2. List of endangered brackishwater and marine species.

English name	Scientific name	Remark
Vertebrates		
Whale shark	*Rhincodon typus*	NC
Pointed sawfish	*Anoxypristis cuspidata*	NC
Largetooth sawfish	*Pristis microdon*	NC
Smalltooth sawfish	*Pristis pectinata*	NC
Longcomb sawfish	*Pristis zijsron*	NC
Humpback grouper	*Cromileptes altivelis*	NC
Slender bamboo shark	*Chiloscyllium indicum*	NC
Grey bamboo shark	*Chiloscyllium griseum*	NC
Shark	*Chiloscyllium plagiosum*	NC
Zebra shark	*Stegostoma fasciatum*	NC
Sicklefin weasel shark	*Hemigaleus microstoma*	NC
Silvertip shark	*Carcharhinus albimarginatus*	NC
Grey reef shark	*Carcharhinus amblyrhynchos*	NC
Pigeye shark	*Carcharhinus amboinensis*	NC
Copper shark	*Carcharhinus brachyurus*	NC
Bull shark	*Carcharhinus leucas*	NC
Blacktip shark	*Carcharhinus limbatus*	NC
Blacktip reef shark	*Carcharhinus melanopterus*	NC
Dusky shark	*Carcharhinus obscurus*	NC
Sandbar shark	*Carcharhinus plumbeus*	NC
Spot-tail shark	*Carcharhinus sorrah*	NC
Shark	*Galeocerdo cuvier*	NC
Milk shark	*Rhizoprionodon acutus*	NC
Grey sharpnose shark	*Rhizoprionodon oligolinx*	NC
Spadenose shark	*Scoliodon laticaudus*	NC
Whitetip reef shark	*Triaenodon obesus*	NC
Bowmouth guitarfish	*Rhina ancylostoma*	NC
Guitar fish	*Rhynchobatus australiae*	NC
Guitar fish	*Rhinobatos granulatus*	NC
Guitar fish	*Rhinobatos schlegelii*	NC
Guitar fish	*Rhinobatos thouini*	NC
Guitar fish	*Rhinobatos typusni*	NC
Brown numbfish	*Narcine brunnea*	NC
Electric ray	*Narcine indica*	NC
Electric ray	*Narcine maculata*	NC
Electric ray	*Narcine prodorsalis*	NC
Numbray	*Narke dipterygia*	NC
Electric ray	*Temera hardwickii*	NC
Short-tail stingray	*Dasyatis brevicaudata*	NC
Cowtail stingray	*Pastinachus sephen*	NC
Spotted eagle ray	*Aetobatus narinari*	NC
Mottled eagle ray	*Aetomylaeus maculatus*	NC
Ray	*Aetomylaeus milvus*	NC
Banded eagle ray	*Aetomylaeus niehofii*	NC

Table 2 (continued from p. 135)

Ornate eagle ray	*Aetomylaeus vespertilio*	NC
Rough cownose ray	*Rhinoptera adspersa*	NC
Flapnose ray	*Rhinoptera javanica*	NC
	Harengula atricaudata	NC
	Dorosoma chacunda	NC
	Dorosoma nasus	NC
Invertebrates		
	Order Antipatharia	CITES
	Order Gorgonacea	CITES
	Order Scleractinia	CITES
	Order Stylasterina	CITES
	Order Heliopracea	CITES
	Order Alcyonacea	CITES
	Order Actinaria	CITES
Scaly giant clam	*Tridacna* sp.	CITES
Trumpet shell	*Charonia tritonis*	CITES

CITES – The Convention of International Trade in Endangered Species of Fauna and Flora
NC – National Concern

Goods Export and Import Act B.E . 2522 (1979)

This Act protects wild animals especially six species of turtles. Exportation of goods made from parts of the turtle or any wild animal must have permits. The export of ornamental marine fish is also prohibited.

Habitat protection and rehabilitation

Habitat protection and rehabilitation are undertaken as follows:

1. The areas of the river near or connected to the temples are considered as "No fishing Zone". Fishing with any type of gear is not allowed in this area.

2. A "Conservation Zone" as declared by the Minister of the Ministry of Agriculture and Cooperatives or Provincial Governor is an area designated for broodstock. Fishing for household consumption can be allowed with the use of some fishing gears such as fishhooks, etc.

3. Thousands of 1.5 m^3 cement structures have been deployed as artificial reefs in several places especially in the Andaman Sea. The smallest area covered by artificial reefs is 0.25 sq km and the largest is 30 sq km. Likewise, the artificial fish habitats have been deployed in rivers. Wood stalks and used rubber tires are utilized as fish shelters in the conservation zone.

Stock Enhancement Program

Species stocked

Fingerlings are collected from the wild and reared to broodstock size at fishery stations. Induced spawning is sometimes done by mobile teams from the Department of Fisheries. The fertilized eggs are moved from the site to hatcheries of the fishery stations. Most of the fingerlings are restocked yearly in natural habitats and the remaining stocks are kept and grown as potential broodstock (Table 4).

Release strategies

Most of the fingerlings of endangered species produced by the Department of Fisheries were stocked in sites where the

Table 3. Some of the endangered species produced by Department of Fisheries, Thailand.

Common name	Scientific name	Production per year (pcs)
Asian bonytongue	*Scleropages formosus*	100-200
Giant softshell turtle	*Chitra chitra*	100-200
Ladderback loach	*Botia sidthimunki*	10,000
Indochina featherback	*Chitala blanci*	100-300
Giant catfish	*Pangasianodon gigas*	100,000
Giant Pangasius	*Pangasius sanitwongsei*	10,000-20,000
Isok barb	*Probarbus jullieni*	200,000-300,000
Giant barb	*Catlocarpio siamensis*	300,000

founder or parental stocks were originally obtained. However, marking or tagging of the released animals was not done. Likewise, impact on catches and cost-benefit analysis were not done.

Government agencies and non-government organizations (NGOs) involved; co-management by local communities and stakeholders

Cooperation in conservation, protection and rehabilitation of aquatic animals in Thailand is quite successful. Several agencies, including NGOs, participate in these activities. One of the Queen's projects, the "Rehabilitation of Marine Fisheries Resources Project" was done in 2002. The project was supported by government agencies and several organizations. About 208 units of cabins from old unused trains and 707 units of damaged cement pipes were donated by the State Railway of Thailand and the Department of Highways for artificial reefs. The Department of Fisheries studied the sites and the impact of the establishment of these artificial reefs to fisheries. The Thai Navy studied their impact on the environment. Cooperation and sharing of resources were discussed by small-scale and large-scale fishermen for the sustainability of the fishery resources.

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Table 4. List of endangered species stocked in the wild by the Thai Department of Fisheries.

Species stocked	No. of pcs	Area covered	First stocking year
Probarbus jullieni	240,000	Whole country	1981
Pangasianodon gigas	50,000-100,000	Whole country	1985
Catlocarpio siamensis	300,000	Whole country	1986
Rana blythii	30,000-50,000	480 ha	1990
Pangasius sanitwongsei	10,000-20,000	Whole country	1999
Botia sidthimunki	5,000	Nan River 5	2003

Endangered Fish Species and Seed Release Strategies in Vietnam

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Introduction

World economic growth has led to considerable changes in the ecosystem in many places and has raised concerns on global resource management particularly aquatic animal resources and their living environment. In Vietnam, aquatic animal resources play an important role in the national economy and are one of the targets for economic development. However, under high population pressure, high demand for seafood has resulted in unfavorable living environment. Aquatic animal resource has been over-exploited and in some places reported to be declining, hence some species have become extinct or endangered.

This paper presents some endangered species, seed production and release strategies for resource conservation.

Endangered Species

Based on the Red Book, various freshwater fish (Table 1) and marine animals (Table 2) have different levels of endangered status.

Reasons for the various species being endangered are as follows:

a) Fishing

High fishing pressure and destructive fishing gears/methods such as trawls, seines, explosives, dynamite, etc., have been used in coastal and inland waters, which resulted in the destruction of habitats and death of animals.

b) Destruction of ecosystem

Mangroves and wetland ecosystems have been converted into aquaculture ponds. Dam construction for irrigation and building of shipping harbors have also affected the ecosystem.

c) Water pollution

Industrial, agricultural and domestic waste discharges reduced the biodiversity and spawning of animals.

Aquatic Resource Management

Although the government of Vietnam has issued many regulations and legislation for environmental and resource management, guidelines and methods for effective implementation are still lacking. Legislation has not been updated.

In recent years, integrated coastal or community-based management programs have been undertaken in Vietnam. Some protected marine areas such as Hon Mun PMA (Nha Trang Bay), Trao Reef (Van Phong Bay), sea garden (Van Phong Bay) have been organized. Likewise, a long-term resource management strategy has been established.

Artificial propagation of many endangered species has not been successfully achieved. Seed production technology has been focused on high value species due to farmers' demands. For endangered freshwater fish, hatching the snakehead fish *Channa striata*, *C. micropeltes* and *C. maculata* has been successfully done. To date, seed production of *Cyprinus centralus*, *Labeo chrysophekadion*

Table 1. List of freshwater fish species that are endangered (E), very endangered (V), threatened (T) and at risk (R). Symbol + indicates the presence of the species in the specified locations.

Scientific name	Status	Location					
		North	Center	Central South	High-lands	Eastern South	Mekong Delta
Scleropages formosus	E					+	
Anguilla japonica	E	+	+				
Procypris merus	E	+					
Cyprinus multitaeniata	E	+					
Tenualosa reevesii	V						+
Hilsa kelee	V				+		+
Hilsa toli	V	+	+				
Clupanodon thrissa	V	+	+				
Konosirus punctatus	V	+					
Laichowcypris day	V	+	+	+			
Onychostoma laticeps	V	+	+				
Semilabeo notabilis	V	+	+	+			
Bangana lemassoni	V	+	+		+		
Spinibarbus caldwelli	V	+		+			
Spinibarbus denticulatus	V	+	+		+		
Cyclocheilichthys enoplus	V					+	+
Tor tambroides	V						
Mylopharyngodon piceus	V	+	+				
Luciocyprinus langsoni	V	+					
Megalobrama terminalis	V	+	+				
Pangasius larnaudii	V			+			+
Hemibagrus elongatus	V	+	+	+		+	
Cranoglanis bouderius	V	+	+	+			
Bagarius bagarius	V	+	+				+
Trichogaster pectoralis	V			+	+		
Chanos chanos	T		+				
Chitala chitala	T			+	+		+
Cyprinus centralus	T						
Catlocarpio siamensis	T			+			+
Squaliobarbus curriculus	T	+	+		+		
Ochetobius elongatus	T	+			+	+	
Cirrhinus microlepis	T						+
Cosmochilus harmandi	T						+
Labeo chrysophekadion	T				+		+
Probarbus jullieni	T					+	+
Channa micropeltes	T						+
Channa striatus	T		+	+		+	+
Toxotes chatareus	R	+					
Anguilla marmorata	R					+	
Anguilla bicolor pacifica	R						
Gyrinocheilus aymonieri	R			+			
Sinogastromyzon tonkinensis	R			+			+
Pangasianodon gigas	R	+	+			+	+

Source: Fisheries Ministry of Vietnam (1996)

Table 2. List of endangered marine animals that are endangered (E), very endangered (V), threatened (T) and at risk (R).

Scientific name	Status	Location
Nematolosa nasus	E	Vietnam sea except for Ca Mau
Anodontostoma chacunda	E	Tonkin Gulf; Thailand Gulf
Crocodylus porosus	E	Eastern; southwest
Crocodylus siamensis	E	High lands; south
Sepia tigris	E	Tonkin Gulf; central south
Trochus niloticus	E	Central south; southeast
Trochus pyramis	E	Central south; southeast
Turbo marmoratus	E	Khanh Hoa province
Anomalocardia squamosa	E	Khanh Hoa province
Gafrarium tumidum	E	Khanh Hoa province
Nautilus pompilius	E	Khanh Hoa and Vung Tau provinces
Loligo formosana	E	Tonkin Gulf; southern center
Chelonia mydas	E	Vietnam Sea
Eretmochelys imbricate	E	Tonkin Gulf; southern center
Dermochelys coriacea	E	Hai Phong, Khanh Hoa and Kien Giang provinces
Microthele nobilis	E	Khanh Hoa province
Thelenota ananas	E	Khanh Hoa province
Bostrichthys sinensis	V	Tonkin Gulf; southwest
Hippocampus trimaculatus	V	Tonkin Gulf
Hippocampus kelloggi	V	Tonkin Gulf
Hippocampus histrix	V	Tonkin Gulf
Hippocampus kuda	V	Tonkin Gulf
Panulirus longipes	V	Center
Panulirus ornatus	V	Tonkin Gulf; center; southeast
Panulirus versicolor	V	Center
Panulirus homarus	V	Center
Sepioteuthis lessoniana	V	Khanh Hoa province
Strombus luhuanus	V	Southern center; southwest
Charonia tritonis	V	Southern center
Haliotis asinina	V	Tonkin Gulf and southern center
Haliotis ovina	V	Tonkin Gulf
Heterocentrotus mammillatus	V	Khanh Hoa province
Actinopyga echinites	V	Khanh Hoa province
Actinopyga mauritiana	V	Khanh Hoa province
Caretta caretta	V	Vietnam Sea
Lepidochelys olivacea	V	Vietnam Sea
Masturus lanceolatus	T	Tonkin Gulf
Rhina ancylostoma	T	Tonkin Gulf
Tachypleus tridentatus	T	Vietnam sea except for southwest
Cypraea testudinaria	T	Khanh Hoa and Quang Ngai provinces
Pocillopora damicornis	T	Southern center; southwest
Pocillopora verrucosa	T	Southern center; central south
Acropora florida	T	Southern center; central south
Elops spp.	R	Nam Ha province
Albula vulpes	R	Nam Ha, southern center
Cyttopsis cypho	R	Tonkin Gulf; southern center
Trachyrhamphus serratus	R	Vietnam Sea
Syngnathus acus	R	Vietnam Sea
Solegnathus hardwickii	R	Center
Ateleopus japonicus	R	Vietnam Sea
Solenostomus paradoxus	R	Nha Trang
Schindleria praematura	R	Tonkin Gulf
Sathyrichthys rieffeli	R	Quy Nhon

Table 2 (continued from p. 141)

Scientific name	Status	Location
Anacanthus barbatus	R	Tonkin Gulf
Oxymonocanthus longirostris	R	Truong Sea
Mola mola	R	Tonkin Gulf
Antennarius striatus	R	Khanh Hoa
Etmopterus Lucifer	R	Tonkin Gulf
Anoxypristis cuspidata	R	Tonkin Gulf
Pristis microdon	R	Tonkin Gulf
Cypraea argus	R	Khanh Hoa province
Cypraea histrio	R	Khanh Hoa province
Cypraea mappa	R	Southern Center
Cypraea spadicea	R	Khanh Hoa province
Cypraea scurra	R	Khanh Hoa province
Ovula costellata	R	Khanh Hoa province
Calpurnus lacteus	R	Center
Calpurnus verrucosus	R	Southern Center
Lambis crocata	R	Khanh Hoa province and Con Dao
Cymatium lotorium	R	Khanh Hoa province
Epitonium scalare	R	Khanh Hoa province and Con Dao

Source: Fisheries Ministry of Vietnam (1996)

and *Cirrhinus microlepis* is being studied. The seedstock of some endangered brackish and marine water species, such as green mussel *Perna viridis*, abalone *Haliotis asinina*, top shell *Trochus niloticus,* have been successfully produced. However, the biology of some important species such as *Panulirus ornatus* and *Actinopyga echinites* are currently being undertaken.

Through the support of the Ministry of Fisheries and many international organizations, such as Support to Freshwater Aquaculture (SUFA), Support to Brackish Water and Marine Aquaculture (SUMA), Danish International Development Agency (DANIDA), World Fish Centre (formerly ICLARM), Southeast Asian Fisheries Development Center (SEAFDEC), Australian Centre for International Agriculture Research (ACIAR), and the Norwegian Centre for International Cooperation in Higher Education (SIU), etc., there have been many projects on seed production and resource conservation in recent years.

In Vietnam, aquaculture is one of the major activities; hence, advanced technology has been of high priority. In 2000-2004, the Ministry of Fisheries carried out over 70 projects on seed production. For freshwater fish, success in the seed production of bighead carp *Aristichthys nobilis*, silver carp *Hypophthalmichthys molitrix,* grass carp *Ctenopharyngodon idella*, common carp *Cyprinus carpio,* etc. was achieved. In recent years, we have given more attention to broodstock improvement. In addition, research projects on some endangered species were initiated and promising results have been achieved for *Hemibagrus elongatus, Mystus wolffii, Silurus asotus*, *Cyclocheilichthys enoplus* and *Cyprinus centralus*. Seed production of tiger shrimp *Penaeus monodon*, mud crab *Scylla serrata*, and swimming crab *Portunus pelagicus* was likewise successful (Research Institute for Aquaculture No. 3, 2004).

Success in seed production has also been achieved for abalone *Haliotis asinina*, oyster *Crassostrea* sp., hard clam *Meretrix lyrata*, blood cockle *Anadara granosa*, babylonia snail *Babylonia areolata*, cobia *Rachycentron canadum*, sea bass *Psammoperca waigiensis* and *Lates calcarifer*, sea cucumber *Holothuria scabra*, sea urchin *Tripneustes gratilla,* and some ornamental fish (Research Institute for

Table 3. Freshwater fish species stocked in Ea Soup reservoir, Daklak province.

Species	2001 (kg)	2002 (kg)	2003 (kg)	2004 (kg)	2005 (kg)	Price (VND)/kg	Total (VND)
Grass carp	90	30	75	52	-	48,000	11,856,000
Silver carp	85	60		120	60	48,000	12,720,000
Rohu	21	39	40	52	105	48,000	7,296,000
Indian mrigal	52	-	-	-	-	48,000	2,496,000
Tilapia	20	-	-	-	-	48,000	960,000
Hybrid carp	-	-	100	6	164	48,000	4,800,000
Total	268	129	215	230	165	-	40,416,000

Source: Database from Project of reservoir and river fisheries management in Mekong Delta basin/DANIDA (2004).

Aquaculture No. 3, 2004). These achievements will diversify the culture of species as well as increase the farmers' income.

Stock Enhancement Program

Stock releasing campaign

The population size of some species has been decreasing and becoming extinct such as Giant barb *Catlocarpio siamensis,* which inhabits the Mekong Delta basin (Research Institute for Aquaculture No. 2, 2002). Seed release of declining aquatic animals has been considered to increase the resources. Restocking of fish in reservoirs and lakes has been implemented but in small-scale. Table 3 shows the freshwater fish species stocked in Ea Soup Reservoir from 2001 to 2005. Likewise, seeds of indigenous fish species such as black sharkminnow, bagrid catfish and mud barb were released in the same reservoir in 2003 (Table 4). In Lak Lake 45 kg of Me hoi were released (DANIDA 2004) in 2003. The marine species released in sea garden in 2005 were top shell, abalone and sand fish (Table 5).

Table 4. Indigenous fish released in Ea Soup Reservoir in 2003.

Species		2003		2004	
English name	Scientific name	Quantity	kg	Quantity	kg
Black sharkminnow	*Labeo chrysophekadion*	61,965	79	3,900	6.5
Bagrid catfishes	*Mystus wolffii*	2,000	2		
Mud barb	*Leptobarbus hoevenii*			2,800	14
Total		63,965	81	6,700	20.5

Source: Database from Project of reservoir and river fisheries management in Mekong Delta basin/DANIDA (2004).

Table 5. Marine animals released in sea garden supported by SUMA –DANIDA in 2005.

Species	Quantity (no. of animals)	Price (VND)/ animal
Top shell	3,000	1,000
Abalone	5,000	1,000
Sand fish	10,000	1,000

Future research on seed production and resource restoration

The following lists of animals (top-down priority) are the priority for future stock enhancement programs in Vietnam.

Marine animals

1. Red lobster *Panulirus longipes*
2. Spiny lobster *Panulirus versicolor*
3. Sea urchin *Heterocentrotus mammillatus*
4. Horseshoe crab *Tachypleus tridentatus*
5. Trumpet triton *Charonia tritonis*
6. Green turban *Turbo marmoratus*

Freshwater fishes

1. Giant barb *Catlocarpio siamensis*
2. Mekong giant catfish *Pangasianodon gigas*
3. Spot pangasius *Pangasius larnaudii*
4. Snakeskin gourami *Trichogaster pectoralis*
5. Japanese eel *Anguilla japonica*
6. Black sharkminnow *Labeo chrysophekadion*
7. Asian catfish *Clarias macrocephalus*
8. Carp *Paraspinibarbus macracanthus*
9. Four-barred tigerfish *Coius quadrifasciatus*

Conclusion

Aware of declining aquatic resources, some endangered species have been highly considered for stock enhancement. Although this program is very new, some activities have been carried out such as reproduction, stock releasing campaigns, and restricting illegal fishing gears. But we lack experience in terms of stock assessment and understanding fish population dynamics, therefore we would like to cooperate with other countries to build up this knowledge.

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