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.

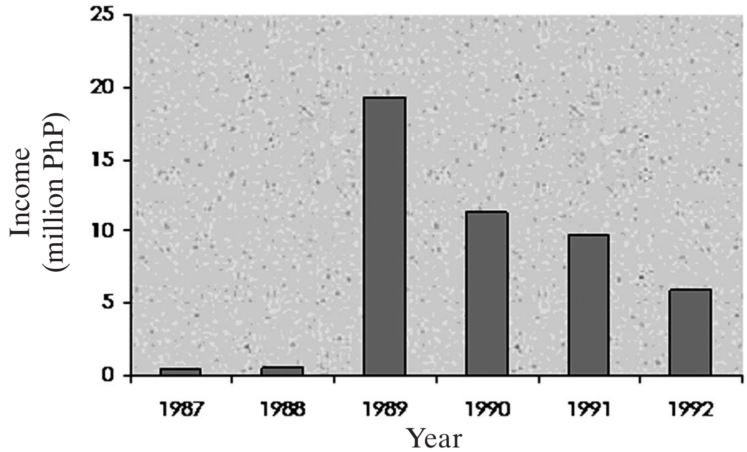

Fig. 1. Annual income from sea urchin fishery in Bolinao, Pangasinan: 1987-1992.

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.

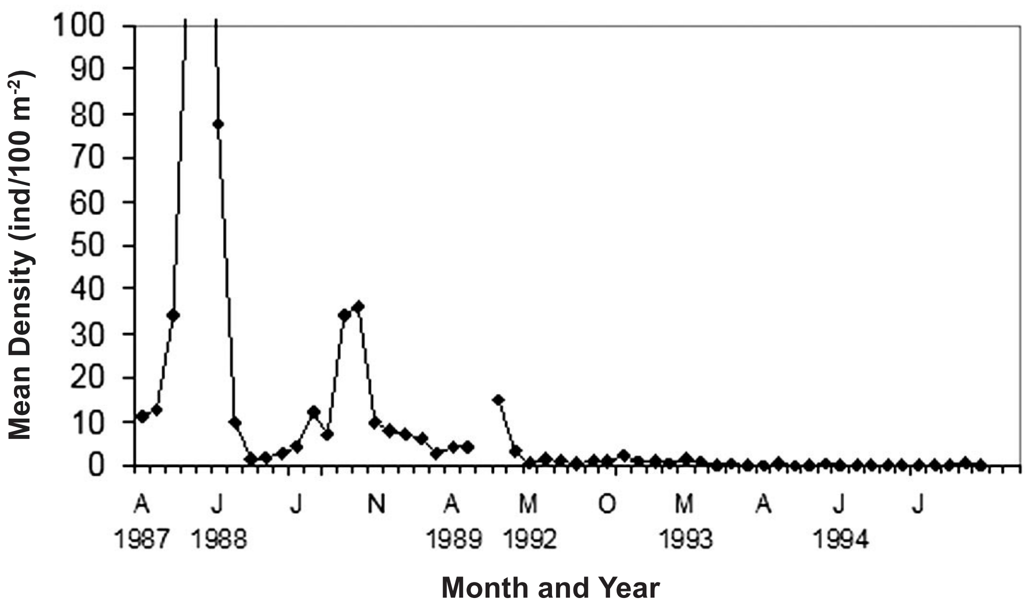

Fig. 2. Mean density of natural *Tripneustes gratilla* populations in Bolinao, Pangasinan: 1987-1994.

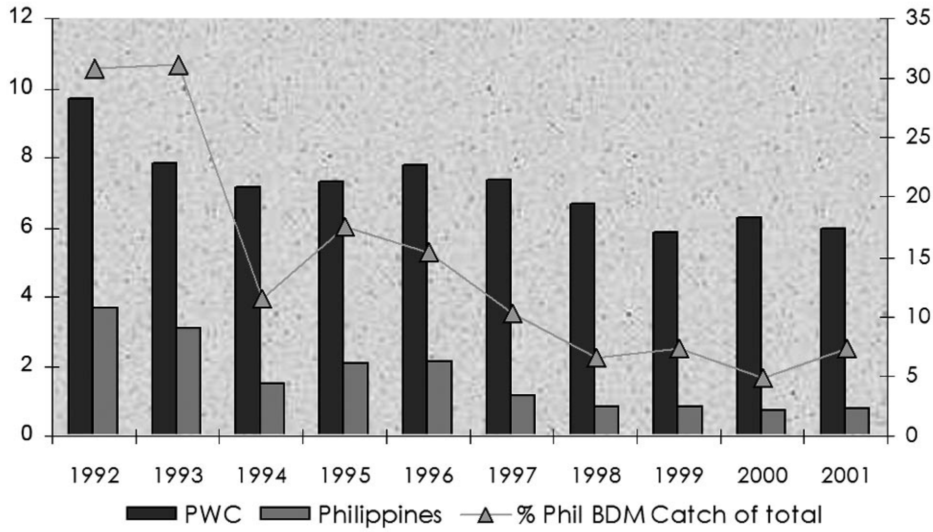

Fig. 3. Production of *beche de mer* from the Philippines and West Central Pacific: 1992-2001 (from Conand 2004).

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

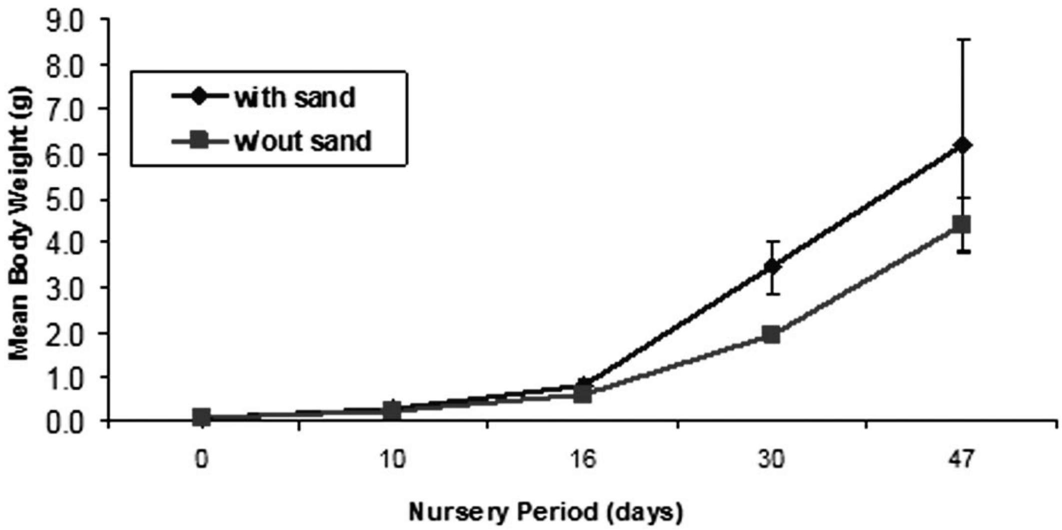

Fig. 4. Body weight (g) of juvenile *Holothuria scabra* in aquaria with and without sandy substrate.

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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