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Restoration of the oriental angelwing (*Pholas orientalis*) resources through broodstock transplantation in Western Visayas, Philippines

[1]Liberato V. Laureta, [1]Lily Anne G. Piñosa, [2]Shirley M. Golez

[1]Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo 5023 Philippines; [2]Institute of Marine Fisheries and Oceanology, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo 5023, Philippines. Corresponding author: L.V. Laureta, jhunlaureta@yahoo.com

Abstract. To arrest the possible extinction of the oriental angelwing (*Pholas orientalis*), broodstock transplantations were tried in the coastal waters of Roxas City in Capiz and in 6 towns and a city (Pulupandan, Valladolid, San Enrique, Pontevedra, Hinigaran, Binalbagan and Bago City) of Negros Occidental. In Roxas City, broodstocks (>6.4 cm in length) were moved either in a bamboo enclosure (area: 100 m^2) (1997) or compartmentalized steel quadrats (area: 1 m^2) (2004); while in Negros Occidental angelwings were transplanted inside concrete culverts (diameter = 1 m; h = 60 cm) (2006) that were half-driven to the bottom substrate and the inside fully filled with muddy clay soil. Sources of broodstock were either Barotac Nuevo in Iloilo or Kalibo in Aklan. Stocking density depended on the availability of broodstocks. In the bamboo enclosure and direct seeding a total 70 individuals were transplanted; 480 individuals for the steel quadrat sanctuaries: and 440-600 individuals for concrete culvert sanctuaries. In all repopulating sites, survival rates of broodstocks were found the range of 0-25%. But, relatively higher survival rates (10-25%) were recorded in Negros Occidental (Valladolid, San Enrique, Pontevedra and Pulupandan), where higher stocking densities were made and with the use of concrete culverts as transplantation sanctuaries. Higher resource productions were observed in Valladolid and Punta Cogon. However, the first harvest (15 tonnes) in Punta Cogon came only after almost 8 years since the replacement, whereas in Villadolid harvest (1.5 tonnes) was realized almost a year after. With a "close season" observed in both sites, the following year Punta Cogon (2006) and Valladolid (2008) attained unprecedented harvest of 70 tonnes and 100 tonnes, respectively valued both at US$ 270,000 (Php 12M). The area covered by *Pholas orientalis* population had widened to 2.5 ha in Punta Cogon and to 30 ha in Valladolid. For the replacements of 2004 in Barra and Cogon in Roxas City, harvests were recorded also a year after the transplantation. However, due to inclement weather condition and uneven harvest these areas were noticed to be once again depleted of the resource the following year. Of the 7 municipalities in Negros Occidental, Bago City, Hinigaran and Binalbagan did not respond to the restoration strategy. The failure of planted stocks to survive in these waters may be attributed to the presence of some industrial establishments (sugar central and liquor factories) that may have affected and deteriorated the quality of water and bottom substrates where the resources used to thrive. In conclusion, broodstock transplantation appears to be a potential strategy to restore angelwings resources, and likewise a potential multi-million source of livelihood for the coastal community residents.
Key words: *Pholas orientalis,* broodstock transplantation, restoration, oriental angelwings, Western Visayas.

Rezumat. Pentru a împiedica posibilitatea de extincţie a scoicilor aripă de înger (mentarang) (*Pholas orientalis*), un efectiv de juvenili a fost transplantat în apele litorale ale oraşului Roxas în Capiz şi în alte 6 comune şi un oraş (Pulupandan, Valladolid, San Enrique, Pontevedra, Hinigaran, Binalbagan şi Bago City) din Negros Occidental. În Roxas City juvenilii (>6.4 cm lungime) au fost transportaţi fie într-o incintă de bambus (suprafaţa: 100 m^2) (1997) fie în tetragoane de oţel compartimentate (suprafaţa: 1 m^2) (2004); în timp ce în Negros Occidental scoicile aripă de înger au fost transportate în rigole de beton (diametru = 1 m; h = 60 cm) (2006) care au fost pe jumătate introduse în substrat şi interiorul a fost umplut în întregime cu sol argilos. Sursele de juvenili au fost fie Barotac Nuevo din Iloilo sau din Kalibo in Aklan. Densitatea stocării a depins de disponibilitatea juvenililor. În incinta de bambus şi prin însămânţare directă un total de 70 de indivizi au fost transplantaţi; 480 de indivizi pentru sanctuarele cu tetragoane de oţel şi 440-600 indivizi pentru adăposturile cu rigole de beton. În toate siturile de repopulare, rata de supravieţuire a juvenililor a fost în intervalul 0-25%. Dar, rate de supravieţuire relativ mai ridicate (10-25%) au fost înregistrate în Negros Occidental (Valladolid, San Enrique, Pontevedra şi Pulupandan), unde au fost aplicate densităţi de stocare mai ridicate şi cu utilizarea rigolelor

de beton ca şi mijloace de transplantare. Producţii mai mari au fost observate în Valladolid şi Punta Cogon. Insă, prima recoltă (15 tone) în Punta Cogon a fost strânsă doar la aproape 8 ani de la relocare, în timp ce în Villadolid recolta (1,5 tone) a fost realizată după aproape un an. Cu o perioadă de prohibiţie implementată în ambele locaţii, in anul următor Punta Cogon (2006) şi Valladolid (2008) au fost atinse recolte fără precedent, de 70 şi respectiv 100 de tone, estimate la 270.000 US$ (12M Php). Suprafaţa acoperită de populaţia de *Pholas orientalis* s-a extins la 2,5 hectare în Punta Cogon şi la 30 ha in Valladolid. Pentru relocarea din 2004 în Barra şi Cogon în Roxas City, recoltele au fost de asemenea realizate la un an după relocare. In orice caz, datorită condiţiilor meteo nefavorabile şi recoltelor neregulate aceste suprafeţe au ajuns să fie din nou cu resursele epuizate în anul urmator. Din cele 7 municipalităţi, Negros Occidental, Bago City, Hinigaran şi Binalbagan nu au răspuns la strategia de restaurare. Eşecul în privinţa supravieţuirii stocurilor plasate în aceste ape se poate datora prezenţei unor obiective industriale (fabrici de zahăr şi alcool) care se pare să fi afectat şi deteriorat calitatea apei şi a substratului unde resursele prosperau în trecut. În concluzie, transplantarea juvenililor pare sa fie o potenţială strategie de restaurare a resurselor de scoici aripă de înger şi implicit o potenţială sursă de hrana pentru subzistenta rezidenţilor comunitatilor costiere.
Cuvinte cheie: *Pholas orientalis,* transplantare de juvenili, restaurare, scoici aripă de înger, Western Visayas.

Introduction. The oriental angelwings, *Pholas orientalis* (Gmelin 1791) are bivalve mollusk that belong to the family Pholadidae, and their distribution is limited in the coastal waters of Australia and some Southeast Asian countries. In the Philippines, these species are endemic in Western Visayas Region particularly in the coastal waters of the provinces of Iloilo, Negros Occidental, Aklan and Capiz (Ablan 1938; Young & Serna 1982; Laureta 2005). Considered as a delicacy, and because of its succulent texture, sweet and juicy taste and unique flavor, *P. orientalis* has become a major source of livelihood for numbers of coastal fishermen and has become a tourist food attraction in major cities and towns in the region. Just like many clams, this bivalve is somewhat expensive and believed to have possessed an aphrodisiac element in it (Ronquillo & McKinley 2006). However, due to over-exploitation and destructive anthropogenic activities, many traditional grounds are found rapidly declining on these resources, and the rest have been depleted already. There is an urgent need to save this endangered species before it becomes extinct in the Philippine waters (Ronquillo & McKinley 2006). Certain actions and active interventions must be undertaken to restore stocks to reproductive viability (Joaquim et al 2007) so that these areas would again become a sustainable source of income for coastal fishermen (Marasigan & Laureta 2001).

Throughout the world, the most active strategies for rehabilitating and restoring coastal mollusk fisheries are through restocking and enhancement (for definitions, see Bell et al 2005; Bell et al 2008). Exemplary approaches include stock management programmes with seeding efforts (Arnold 2008), direct release of larvae (Preece et al 1997; Shepherd et al 2000; Arnold et al 2002; Murphy et al 2005; Ronquillo & McKinley 2006), the dispersal of cultured juveniles (Honma 1980; Chen 1984; Inoue 1984; Oshima 1984; Schiel 1993; Turner & Soares 1994; Kojima 1995; Peterson et al 1995; Marelli et al 1996; Kitada & Fushimi 1997; Arnold et al 2002; Bell et al 2005; Gomez & Mingoa-Licuanan 2006), and relocating and aggregating hatchery-breed or wild sub-adults or adults (Peterson et al 1996; Turner & Soares 1994; Arnold et al 2002; Peterson 2002; Doall et al 2003; Purcell 2004; Davis et al 2006; Joaquim et al 2007).

Restocking and enhancement using hatchery-raised juveniles and larvae are by far the most common strategies for restoration of fishery resources in many parts of the world. Application of these technologies, however, appears not feasible in the Philippine situation to date, particularly for the *P. orientalis* since no hatchery technology has been developed yet for this clam. Besides, there is already an urgent appeal from the coastal populace and government officials of some affected areas for our immediate intervention. Therefore, this study is the first effort to determine the enhancement potential of wild broodstocks of the oriental angelwings for the restoration of some depleted beds in Western Visayas. Practically, our goal is to restore the spawning biomass of the severely depleted population of this clam to a level where they can once again provide regular and substantial yields (Bell et al 2005). In this study, as possible, we determined the survival of transplanted broodstocks, density and period of appearance of recruits, and harvest. Further, we evaluated the different transplantation structures as restoration sanctuaries for the angelwing. Moreover, we take note of the effect of employing "close season" strategy to sustainability of the resource.

Materials and Methods

Our restoration strategies were focused in Roxas City, Capiz (122º45′E and 11º37′N) (1997 and 2004) and in the southern Negros Occidental (122º48′E and 10º29′N to 122º51′E and 10º40′N) (2006) (Fig. 1), areas in Western Visayas noted to have a depleting beds of the oriental angelwings, *P. orientalis*. The scarcity of broodstocks from source (Barotac Nuevo, Iloilo and Kalibo, Aklan) enabled us to limit stocking densities in all transplantation sites.

1997: Roxas City Broodstock Transplantation. Two areas in Roxas City, Capiz were identified as study sites for *P. orientalis* broodstock transplantation. These two sites are part of the fish sanctuary declared by the city government. The first site (station 1) was in the coastal water of Punta Cogon. This site is considered sublittoral, and water depth is about 8 m. A bamboo enclosure with an area of about 100 m^2 was installed at the center of the station, which served as broodstock sanctuary, and area outside this structure served as the recruitment area. A reflectorized signage was posted on the enclosure as navigational guide for fishermen especially during the night.

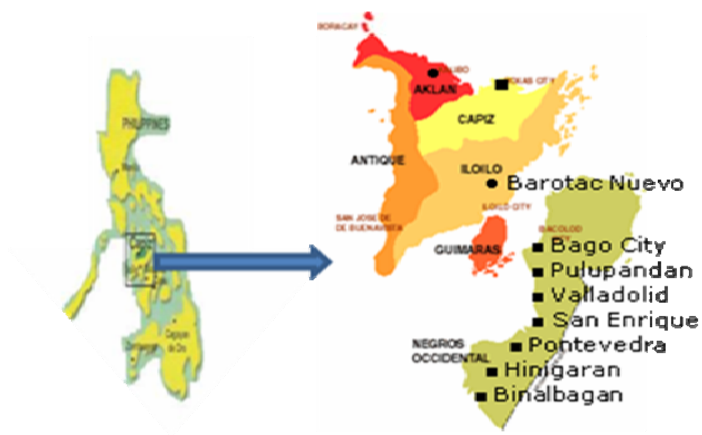

Fig. 1. The different study sites (■) for the broodstock transplantation: Roxas City, Capiz (1997; 2004); Negros Occidental (2006). Broodstock sources (●)

The second site (station 2) was in the coastal water of Barra where water depth is < 1-3 m. No structure similar to that described above was constructed, and transplantations were done by direct seeding at the middle of station in aggregation. Ecological information (substrate type and physic-chemical characteristics of water) about the coastal water of Roxas City was described by Laureta & Marasigan (2000).

All transplanted *P. orientalis* broodstocks were purchased from fishermen, and originated from Barotac Nuevo, Iloilo (122º47′E and 10º55′N). A total of 70 individuals (size length (SL) range: 9.8–15.8 cm) (Table 1) were transplanted in August 1996.

The whole clam was planted inside a made-hole to prevent their predation from carnivorous crustaceans and mollusks in the area. All transplanted clams were sexually mature (Laureta & Marasigan 2000), but no attempt was made to determine the reproductive conditions of these bivalves prior and after transplantation.

Table 1

Data on the transplanted broodstocks *Pholas orientalis* at different period of transplantation in Western Visayas, Philippines

Localities	Transplantation Structure Type	Number	Stocking Data Per structure	Total stock	Mean SL (cm)	SL range (cm)
1997: Roxas City						
Punta Cogon	Bamboo enclosure	1	70	70	12.84±1.72	9.8–15.8
Barra	Open water (direct seeding)	1	70	70	12.84±1.72	9.8–15.8
2004: Roxas City						
Cogon	Steel quadrats	20	24	480	8.7±1.36	6.5–11.4
Barra	Steel quadrats	20	24	480	8.7±1.36	6.5–11.4
2006: Negros Occidental						
Bago City	Conc. culverts	19	25	475	8.04±0.98	6.4–10.1
Pulupandan	Conc. culverts	30	20	600	8.6±1.24	6.5–11.2
Valladolid	Conc. culverts	30	20	600	8.6±1.24	6.5–11.2
San Enrique	Conc. culverts	30	20	600	8.6±1.24	6.5–11.2
Pontevedra	Conc. culverts	22	20	440	8.04±0.98	6.5–10.1
Hinigaran	Conc. culverts	20	25	500	8.4±1.10	6.5–10.5
Binalbagan	Conc. culverts	30	20	600	8.4±1.10	6.5–10.5

Population of transplanted clams was monitored on October 14, 1997 to determine survival rate for both station. As these clams are deep burrowers (0.3 m) (Laureta & Marasigan 2000; Ronquillo & McKinley 2006), presence of protruding siphons probing at the bottom of the sea or undisturbed burrows were our basis that they are alive. However, follow up monitoring in 1998 for both stations was not possible because enclosure in station 1 was heavily damaged by the strong typhoon that passed through the region during that year, leaving no trace where the former sanctuary was. Neither the sanctuary in station 2 can be located because identification marker disappeared. From this date on, no biological information was gathered on the transplanted stocks. Despite this situation, the Local Government of Roxas City promulgated in 1999 the banning of harvesting of angelwings and trawling near or at the declared clam sanctuary of the city.

On March 2004, with funding support from the national government to re-assess angelwing populations in the region, we were able to find in Punta Cogon (station 1) a very dense population of varied sizes of this bivalve. Because of this new development, the local government issued a no harvest regulation for this area until such a time that "open-season" was declared. While waiting for the angelwings in the upper mud substratum to grow to marketable size (> 6 cm), policies and regulations as to the harvest, conservation and protection of the new found population were formulated.

In May 2004 started the harvest of the clam and ended up in July 2004. Random weighing and sizing of collected clam during different dates of harvest was conducted. Assessment of the remaining population was conducted in July 2004.

In Barra (station 2), we were informed that harvesting started in February 2004 without the sanction of the local government. In July 2004, Barra was already depleted of the resource.

After a strict implementation of a regulation of "no-take zone" in Punta Cogon, a much larger "tuklas" (Filipino dialect meaning, "great abundance") was discovered in May 2005. Harvest started in July 2005 and ended in October 2005.

2004: Roxas City Broodstock Transplantation. There was a good harvest of *P. orientalis* in Punta Cogon (station 1) in 2004. However, the coastal people strongly believed that the "tuklas" observed for this clam is compared to the mushroom that just pop out from nowhere at an opportune time. They doubted the effect of broodstock transplantation as restoration strategy because it took about 8 years before "tuklas" was attained. With this, we decided to replicate the restocking as a restoration strategy.

Two (2) sanctuaries were established, and exact locations were determined using the Global Positioning System (GPS). The first sanctuary (station 1) was in the deeper part (> 3 m) of Barra; while the second sanctuary (station 2) was situated in Cogon.

Instead of a bamboo enclosure, 20 yellow painted steel quadrats (1.2 m x 0.8 m) were installed about 1 m apart in each sanctuary. Each quadrat was composed of 24 compartments and each compartment was transplanted with 1 broodstock. A total of 480 individuals were transplanted for each sanctuary. The broodstock transplantation was conducted in October 2004. The transplants with an average size length (SL) of 8.7±1.36 cm (SL range: 6.5-11.4 cm) were purchased from fishermen who gathered them from Kalibo, Aklan (122º51'E and 11º42'N). Our histological analysis showed that the transplanted angelwings already were mostly in their ripe reproductive stages.

On October 23, 2004, monitoring was conducted in both sites to determine mortality of the transplanted stocks. There was a relatively good juvenile population observed in Cogon and Barra in January 2005, and this population was harvested in July 2005. The declaration of a "close season" was not implemented because almost the entire *P. orientalis* bed in the two sites after the harvest was covered by sand due to inclement weather that passed the sites. The unaffected area was poached and the steel quadrats were reportedly taken.

2006: Negros Occidental Broodstock Transplantation. The unprecedented harvest record of *P. orientalis* in Punta Cogon in 2005 was known by the local and provincial government officials of Negros Occidental. Seven municipalities (Bago City, Pulupandan, Valladolid, San Enrique, Pontevedra, Hinigaran and Binalbagan) all belonging to Central Negros Council for Coastal Resources and Development (CENECCORD), favorably decided to adopt the broodstock transplantation to restore their angelwing resource.

In this restoration activity, we used concrete culverts as transplantation structures. The culvert (diameter = 1 m; height = 0.6 m) which was painted with reflectorized yellow color at the top edge, was driven half of its height to the bottom substrate and then the inside was fully filled with muddy clay soil. A total of 19 to 30 culverts were installed in each municipality and the aggregation of culverts formed the broodstock sanctuary. All sites were previously considered as traditional grounds of angelwings. We used the GPS to determine the coordinates of these sites. Established sanctuary was inside the Marine Protected Area (MPA) declared by the municipality.

Because of unavailability of enough broodstock supply from Kalibo, Aklan, the transplantation activities were staggered. Sanctuaries in Bago City and Pontevedra were transplanted in July 2006 (mean size length (SL): 8.04± 0.98 cm; SL range: 6.4-10.1 cm); those in Binalbagan and Hinigaran in August 2006 (mean SL: 8.40±1.16 cm; SL range: 6.5-10.5 cm); in October 2006 transplantation took effect for Pontevedra, Pulupandan, Valladolid and San Enrique (mean SL: 8.6±1.24 cm; SL range: 6.5-11.2 cm). For each culvert we transplanted 20-25 individuals.

A single monitoring of survival of stocks in all sites was made only on November 22 to 23, 2006. Then this was followed by harvesting after over a year.

Results

Table 2 presents the survival rates and recruitments of the broodstock transplants from the different localities in Roxas City and Negros Occidental at the different period of broodstock transplantation.

Table 2

Survival rates of *Pholas orientalis* broodstocks transplants and observed recruitments from different localities in Western Visayas, Philippines

Localities	Type of structure	Transplanted broodstock Total Stock	Surv. Rate (%)	Recruitments Appearance after transplant	Density (m^2)	Area covered (ha)
1997: Roxas City						
Punta Cogon	Bamboo enclosure	70	7.0	7 yr & 9 mos.	30.35	1
Barra	Open Water (direct seeding)	70	5.71	(no data)		
2004: Roxas City						
Cogon	Steel quadrat	480	6.25	97 days	90	0.25
Barra	Steel quadrat	480	6.25	96 days	40	0.25
2006: Negros Occidental						
Bago City	Conc. culvert	475	0	No data (no follow up)		
Pulupandan	Conc. culvert	600	10.1±4.5	No data (no follow up)		
Valladolid	Conc. culvert	600	24.78±7.1	No data (no follow up)		
San Enrique	Conc. culvert	600	21.89±7.0	No data (no follow up)		
Pontevedra	Conc. culvert	440	11.44±3.7	No data (no follow up)		
Hinigaran	Conc. culvert	500	0	No data (no follow up)		
Binalbagan	Conc. culvert	600	0	No data (no follow up)		

On the other hand, the initial data on harvest after transplantation and the subsequent or following year harvest data after the implementation of "close season" regulation are presented in Table 3 and Table 4, respectively.

Table 3

Initial harvest of *Pholas orientalis* from the different transplantation beds in Western Visayas, Philippines (1US$ = PhP48)

Localities	Type of Structure	First Year Harvest Total wt (kg)	total count	Mean wt. (g)	Mean SL (cm)	Harvest area (ha)	Value (PhP)
1997: Roxas City							
Punta Cogon	Bamboo Enclosure	$1.5x10^4$	$2.98x10^5$	51.0±20.6	9.4±1.5	1	2.25M
Barra	Open water (direct seeding)		(no data)				
2004: Roxas City							
Cogon	Steel quadrat	$7.0x10^3$	$1.57x10^5$	44.3±13.9	9.4±1.2	0.5	1.05M
Barra	Steel quadrat	$1.0x10^3$	$8.0x10^3$	124.0±13.9	13.8±1.1	0.25	0.40M
2006 : Negros Occidental							
Bago City	Conc.culvert		No harvest				
Pulupandan	Conc.culvert	$0.5x10^3$	$1.31x10^4$	38.1±13.8	8.78±1.4	0.5	0.075M
Valladolid	Conc.culvert	$1.5x10^3$	$3.22x10^4$	46.4±7.9	8.5±0.94	1	0.225M
San Enrique	Conc.culvert	$1.5x10^3$	$2.68x10^4$	55.9±9.1	9.1±0.7	1	0.225M
Pontevedra	Conc.culvert	$1.5x10^3$	$3.31x10^4$	45.3±8.4	8.5±0.9	1	0.225M
Hinigaran	Conc.culvert		No harvest				
Binabagan	Conc.culvert		No harvest				

Table 4

Harvest of *Pholas orientalis* from the different transplantation beds in Western Visayas, Philippines a year after initial harvest, with or without regulation (close season) (1 US$ = PhP48)

Localities	Type of structure	Regulation Harvest Total wt (kg)	Total count	Mean wt. (g)	Mean SL (cm)	Harvest area (ha)	Value (PhP)
1997: Roxas City							
*Punta Cogon	Bamboo enclosure	$7.0x10^4$	$1.56x10^6$	44.7±13.9	9.8±1.2	2.5	12.0M
Barra	Open water (direct seeding)			depleted again			
2004: Roxas City							
Cogon	Steel quadrat			depleted again			
Barra	Steel quadrat			depleted again			
2006: Negros Occidental							
Bago City	Conc.culvert			still depleted			
*Pulupandan	Conc.culvert			still closed season			
*Valladolid	Conc.culvert	$1.0x10^5$	$1.73x10^7$	57.9±11.3	9.3±0.8	30	12.0M
*San Enrique	Conc.culvert		no harvest undertaken (remained closed season)				
*Pontevedra	Conc.culvert		no harvest undertaken (remained closed season)				
Hinigaran	Conc.culvert			still depleted			
Binalbagan	Conc.culvert			still depleted			

*Close season was declared for 1 year after the first harvest.

1997: Roxas City Broodstock Transplantation. Few weeks after transplantation, 5 to 7% of 70 transplanted broodstock was found alive. But, due to the unfortunate disappearance of the bamboo enclosure sanctuary in Punta Cogon and the loss of any track of the sanctuary in Barra in 1998, these enabled us to suspend gathering information on the mortality of transplants, occurrence and density of recruitments from this period until March 2004. However, in April 2004, with our newly funded survey project, we were able to find "tuklas" at density of 30-35 ind.m^2 with size length (SL) range of 6.4–10.7 cm (mean SL = 8.36±1.16 cm) and laid in area of about 1 ha. In May 2004, harvest was declared open in this station. From the opening harvest until July 2004, which was declared "closed season", a total of 24 harvesting days were conducted. Harvesting was done by diving with air compressors. Recorded harvest was 15 tonnes, with mean wt. of 51±20.61 g and mean SL of 9.44±1.52 cm (SL range: 7.5–12.7 cm). The estimation of harvested individuals was 298,000.

With off season, our survey showed that *P. orientalis* population remaining in Punta Cogon was at 0.30 ind/m^2 or 3,000 ind.ha^2. After a strict implementation of "no take zone" in May 2005, we found that the area covered by the population of angelwings extended to 2.5 ha and density was recorded at about 90 ind. m^2 with SL range of 4.5 to 9.1 cm. Harvest began in July 2005 and ended in October 2005. Total individuals harvested were estimated to be 1,564,600, equivalent to 70 tonnes, with mean weight of 44.74±13.88 g and mean SL of 8.60±1.19 cm.

In Barra, there was no record of harvest of angelwings. We were informed that angelwings were poached especially during the night by fishermen since February 2004.

2006: Roxas City Broodstock Transplantation. Out of the 480 transplants, we found survival rates of 6.25% (30 ind/m^2) from Cogon and Barra stations, 10 days after the transplantation on October 13, 2004. Recruits (1 cm length) were observed then, after almost 3 months, at 90 ind/m^2 and 40 indm^2. However, observed populations were decimated because of inclement weather that resulted to burying most of the clams with unwanted thick mat of sand. Hence, harvestable area for the angelwings was reduced to 0.25 ha for both sanctuaries. Harvest was conducted in July to October 2006, with records of 7 tonnes in Cogon (mean wt.: 44.3±13.88 g) and 1 tonne (mean wt.: 124.74±13.88 g) in Barra. Poaching was reported in both areas after the local government declared harvest closed. Some steel quadrats were also reported to have been stolen.

2006: Negros Occidental Broodstock Transplantation. We did not find alive broodstock in Bago City, Hinigaran and Binalbagan during our monitoring. Sanctuaries in Pulupandan and Pontevedra had almost identical survival rates of 10.1± 4.51% and 11.4±3.74%, respectively. Valladolid got the highest survival rates (24.78±7.08%), followed closely by San Enrique (21.09±7.04%). No survival data was obtained hereon until the first declared harvest on April 2008 because our funding support was cut due to unavoidable circumstances. Hence, there were no records of the occurrence and density of recruits from all the areas. Recorded harvest in Valladolid, San Enrique and Pontevedra were identical at 1.5 tonnes in 1 ha angelwing beds. Pulupandan had a record harvest of 0.5 tonne in 1 ha. As expected, there was no harvest made for Hinigaran, Binalbagan and Bago City.

Hinigaran, Binalbagan and Bago City still remained devoid of angelwing resource a year after. For Pulupandan, Pontevedra and San Enrique they still continued ban for the harvest of *P. orientalis* the next year as population appeared low to warrant commercial harvest. However, for Valladolid which declared "close season" for one year was found for presence of "tuklas" in two sites during the survey, covering a growth area of 30 ha. In December 2008, the local government opened the harvest and lasted until April 30, 2009. With 400 fishermen involved, a total harvest of about 100 tonnes was recorded with estimated total count of 17.3 million individuals. Mean weight of 57.86± 11.3 g and mean SL of 9.26± 0.83 cm (SL range: 7.1–11.1 cm) were calculated for the harvested population. Estimated value for this harvest was US 270,000 (= PhP 12M).

Testing the viability of different transplantation structures (bamboo enclosure, open water (direct seeding), steel quadrats and concrete culverts) as sanctuaries in respect to survival was evaluated in this study. As shown in Table 2, the use of concrete culverts appeared to be the best method for obtaining higher survival rates of transplants as compared to others.

Discussion. Restoration efforts on shellfish resources have been on-going throughout the world with main objective of augmenting the fished population and catches. Two approaches are popularly applied, which involve: 1) the culture of clams in the laboratory with the subsequent field planting of offspring, either the larvae or juveniles (Loosanoff & Davis 1963; Honma 1980; Chen 1984; Inoue 1984; Oshima 1984; Schiel 1993; Turner & Soares, 1994; Kojima 1995; Peterson et al 1995; Marelli & Arnold 1996; Kitada and Fushimi 1997; Arnold et al 2002; Arnold et al 2005; Bell et al 2005; Gomez & Mingoa-Licuanan 2006), and 2) harvesting clams from the wild populations and translocating them at targeting sites of enhancement (Mason 1969; Malouf 1989; Turner & Soares 1994; Marelli & Arnold 1996; Peterson et al 1996; Arnold et al 2002; Peterson 2002; Doall et al 2003; Purcell 2004; Davis et al 2006; Joaquim et al 2007). One glaring disadvantage however, on the application of the latter, is the conflict that may arise among competing user groups because shellfish population is being depleted to some degree in an effort to restore another population (Arnold 2008).

In this study, we chose to adopt the second approach in as much as there is no technology yet for the hatchery of *P. orientalis*. Moreover, there is an urgent and compelling request to restore the depleted resources in order to avoid impending extinction of the species. Laureta (2005) identified that the major reason for the loss of angelwing population in most traditional grounds in Western Visayas was overexploitation. As such, considerable number of breeders was lost and downgraded the reproductive viability of these beds to almost nil. It is a situation where the population has declined below a point of recovery, when recruitment of offspring will not overcome the mortality of adults in population (Gascoigne & Lipcius 2004). Our ultimate goal of stocking adult shellfish in this study was for them to spawn sooner and then the subsequent recruitment thereby speeding the recovery of the area, and become sources of livelihood again for coastal community residents.

Recovery of Punta Cogon to productive capacity to supplement the livelihood of the residents did not come not until about 8 years after the transplantation conducted in 1996. It was assumed that reproductive activities of *P. orientalis* in this area were very slow considering a low stocking rate (70 ind/area^1) was applied. The replication of the same technology to Roxas City (Cogon and Barra) again using steel quadrats but with higher stocking rates of 480 ind.area^1 and to some municipalities (Valladolid, San Enrique, Pontevedra and Pulupandan) of Negros Occidental using concrete culverts as sanctuaries at even higher rates of 440–600 ind.area^1 hastened rehabilitation of these beds. Recruitment was observed already in few months (Roxas City) after transplantation and the harvest took place slightly over a year in Barra and Cogon in Roxas City, as well as for the above mentioned 4 municipalities in Negros Occidental. Interestingly, all these areas received stocks which were on their ripe reproductive stage prior to spawning.

Stocking adult shellfish at relatively higher densities is likely to improve the chances of successful spawning and reproductive success and consequently better production. This strategy was already found useful as "jump starting" population for species like scallops (Peterson et al 1996), oysters (Southworth & Mann 1998; Braumbaugh et al 2000a and 2000b), and clams (Stewart & Creese 2002). Further, Summerson & Peterson (1990) stressed that population size is recruitment limited and low population sizes is related to low spawning stock biomass. The inverse relationship between size and mortality, expressed as prey size refuge (Arnold 1984; Peterson et al 1995) was ascribed for the failure of stock enhancement of some mollusk species. Our study mainly focused on the adult size population.

Harvest culminated the restoration efforts of this study. Except in Bago City, Hinigaran and Binalbagan where no harvest was made, expanse of recruitment and growing areas appeared limited confined only to ≤ 1 ha when immediate effects of the transplantation are taken into consideration. This could be partly attributed to relatively low survival rates of the transplants in all areas. No surviving transplants in areas where there were no harvests. The survival rates for Valladolid (mean = 24.78± 7.08% cm; range: 13-34%) and for San Enrique (mean = 21.89±0.83 cm; range: 11-32%) were significantly higher, but results were taken 53 days after transplantation. On the other hand, Barra and Cogon in Roxas City, in the second attempt of restoration, had a survival rate of 6.25% after 7 days from the initial transplant. The transplanted stocks are expected to replenish the population of the resource. More stocks will result to more spawning and increased fertilization success, and the eventual larger population of larvae for widely distribution in their natural habitat. However, where there was survival, rates obtained in this study are comparable if not better than those obtained for hard clams and scallops (Flagg & Malouf 1983; Peterson et al 1995; Marelli & Arnold 1996; Arnold et al 2002, 2005); but definitely lower than those obtained for other bivalves (Joaquim et al 2007). The high mortality rates observed particularly in the early few days after transplantation could be attributed to failure of the transplants to burrow quickly deeper into the sediment (Arnold et al 2002), due to their age and health condition as observed in this study where predators took advantage of them. Predation is the dominant controlling factor of clam abundance (Carriker 1959, 1961; MacKenzie 1977; Peterson 1979, 1982; Virnstein 1977). The portunid crabs, *Callinectes* spp. dominated the predator population in our study areas.

The substrate movement during storms has been observed to effect the decimation or further decline of the transplant population, especially in areas where a river is situated close to it (e.g. Barra). On the other hand, the failure of planted stocks to survive in waters of Bago City, Hinigaran and Binalbagan may be attributed to the presence of some industrial structures that may have affected and deteriorated the quality of water and bottom substrates where the resources used to thrive. However, a rerun of the technology is to be conducted to confirm or negate our assumption.

With transplantation structures used as sanctuaries, it would appear that the concrete culverts gave better survival rates than the steel quadrats and bamboo enclosures. In effect, the situational higher elevation and confinement of the transplanted shells inside the culvert made them more protected from adverse effects of inclement weather and predations. While few studies, if at all, have been conducted for adult transplants, the use of some devices as protection especially for seed clams has long been emphasized (Kraeuter & Castagna 1977; Flagg & Malouf 1983) to provide habitat stabilization as well as predation reduction and physical barriers (Menzel & Simms 1964; Goldwin 1968; Eldridge et al 1976).

The integration of policies and regulations for the conservation and sustainability of established new shellfish population as a result of our stock enhancement efforts, undoubtedly, was the main contributory factor for the unexpected and unprecedented harvests in Valladolid and Punta Cogon. Where a population of 0.30 adult m^2 or 3,000 adult.ha^2 left in Punta Cogon prior to the declaration of the "close season", the succeeding year resulted to almost 5x greater harvest (70 tonnes) compared to the previous year (15 tonnes). On the other hand, after 6 months of "no take zone" regulation in Valladolid the harvest had gone up from 1.5 tonnes to about 100 tonnes. Unfortunately, there was no information as to how much was left prior to the declaration of said regulation. Interestingly, the 70 tonnes harvest landing in Punta Cogon was valued to US$ 270,000 (PhP 12 M) and the 100 tonnes for Valladolid were also worth US$ 2.7 M (PhP 120 M). This result although not replicated as must be needed shows that the angelwings industry is potentially geared toward a multi-million industry. However, it should be noted that stock enhancement effectiveness depends on how well stocking is integrated with other management strategies. Stocking technology must be coupled with adequate regulations; it cannot be effective by itself as a strategy for managing fisheries targeting coastal stocks (Leber 2004).

Conclusion. The broodstock transplantation is a potential strategy for the rehabilitation of depleted beds of angelwings, and undoubtedly, a potential multi-million source of livelihood for the coastal community residents. Transplantation of ripe broodstocks in greater number will result to increase reproductive capacity of restored area and earlier recruitment will be noted. The type of substrate for transplants may affect their survival, and in this study elevated substrate such as the culvert appeared the best option. The declaration of close season seems a good strategy for continuous production of the resource. But there is a need to determine optimum residual number of adults after harvest to ensure yield sustainability. Moreover, in order for restoration to become more effective, the following should be considered: density of stocking, quality (healthiness) of broodstocks, area span of habitat, releasing method and environmental conditions.

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Authors:
Liberato V. Laureta, Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo Philippines 5023; e-mail: jhunlaureta@yahoo.com
Lily Ann Piñosa, Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo Philippines 5023; e-mail: l_pinosa@yahoo.com
Shirley M. Golez, Institute of Marine Fisheries and Oceanology, University of the Philippines Visayas, Miagao, Iloilo Philippines 5023; e-mail: shiegolez@gmail.com

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