Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 22

Indications of Recruitment Enhancement in the Sea Urchin *Tripneustes gratilla* Due to Stock Restoration Efforts

M. A. Juinio-Meñez[1] , D. Pastor[1] and H. G. Bangi[2]
[1]Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City 110
[2]College of Aquatic Sciences and Applied Technology, Mariano Marcos State University, Currimao 2903, Ilocos Norte, Philippines

Abstract Field monitoring activities were conducted in various sites in five provinces in northwestern Philippines in 2004-2007 to assess the impacts of restocking and grow-out culture of hatchery-reared *Tripneustes gratilla* juveniles. High incidences of recruits (<4.0 cm test diameter) were noted during the last quarter of 2005 through the first quarter of 2006. Very high densities (up to 460 individuals 100 m^{-2}) were recorded in Lucero, Bolinao, Pangasinan, which is the site for sea urchin broodstock and grow-out cages. Eighty percent of the total density was comprised of recruits of the year. In Sinait, Ilocos Sur, total density and incidence of recruits were significantly higher (up to 67 individuals 100 m^{-2}) than two sites in Ilocos Norte where there was no grow-out culture of sea urchins. In Poro Pt., La Union sea urchins increased after the initiation of grow-out culture activities in 2005 and peaked at 14 individuals 100 m^{-2} in 2007. The positive correlation in the density of recruits and adults in four sites in Bolinao together with the higher densities and incidence of recruits in different grow-out areas concur with the hypothesis that the aggregation of adults in grow-out culture areas enhanced benthic recruitment.

Keywords: recruitment, sea urchins, grow-out culture, stock restoration

Introduction

The reef flats of the coastal municipality of Bolinao, Pangasinan were a prime sea urchin fishing area for *Tripneustes gratilla* in the 1970s through the late 1980s. Unregulated harvesting precipitated in the collapse of the fishery in 1992 (Juinio-Meñez et al. 1998). Hatchery culture was initiated in 1994 and juvenile production was scaled-up by 1996 for restocking to enhance the recovery of the sea urchin fishery in Bolinao. To optimize survivorship of the limited numbers of hatchery-reared juveniles to adulthood, community-based grow-out culture was developed as an adaptive resource management tool to address both ecological and socio-economic considerations while rebuilding the spawning population (Juinio-Meñez et al. 1998). From 2000 to 2006, about 50,000 juveniles were used annually for restocking in selected protected areas and grow-out culture in the Bolinao area. After the Bolinao fishery collapsed in 1992, no natural recruitment was evident until 1999 when a few juveniles were first reported again. During the last quarter of 2004, a strong recruitment pulse was noted together with the increase in the landed catch of collectors, indicating recovery of the natural population in Bolinao. This was further boosted by an even stronger recruitment during the last quarter of 2005 through the first half of 2006 (Juinio-Meñez et al. 2008).

Sea urchin grow-out culture in sea cages was promoted and expanded in the provinces of Ilocos and La Union using wild juveniles to reestablish viable spawning populations and provide a supplemental source of livelihood for fishers in collaboration with fisher's organizations, local government units, regional state universities and the Bureau of Fisheries and Aquatic Resources (BFAR). Among these sites were Sinait, Ilocos Sur and Poro Point, La Union. In Sinait, Ilocos Sur, three to six cages with 500-700 sea urchins per cage were maintained near a marine protected area since 2004. In Poro Point, La Union, a total of 30,000 juveniles (i.e. 60 cages stocked at 500 urchins per cage) were used for the grow-out cages starting December 2005.

Methodology

Data on densities and size frequency distributions of *T. gratilla* derived from field monitoring activities in 2004 -2007 in selected sites in NW Luzon (Fig. 1) were analyzed to gain more insights on the ecological impacts of restocking and grow-out culture of sea urchins.

The total density of sea urchins (individuals 100 m^{-2}) and the density of recruits (<40 mm TD, individuals 100 m^{-2}) at four sites in Bolinao, Pangasinan (Lucero, Silaki Is., Victory and Balingasay, see map inset in Fig. 2) in

2004 to 2007 were compared. Three belt-transects (100 m x 2 m) covering an area of 600 m^{-2}, were surveyed. Sea urchins found within the belt transects were counted and test diameter (TD) was measured to the nearest millimeter using a Vernier caliper. To determine broad scale patterns in recruitment, 6 other locations were surveyed along NW Luzon in January to February 2006 coinciding with the incidence of very high densities of recruits in Bolinao. The four localities surveyed north of Bolinao were Santiago and Nalvo in Ilocos Sur, Paraoir and Poro Point in La Union (Fig. 1). There was on-going grow-out culture of sea urchins in these sites. Whenever possible, additional transects were laid at different distances (10 m apart up to 50 m) from the area of the grow-out cages and another transect in an area with no grow-out cages. South of Bolinao, surveys were conducted at the Hundred Island National Park in Alaminos, Pangasinan (inside Lingayen Gulf) and at three sites in Masinloc, Zambales (Fig. 1).

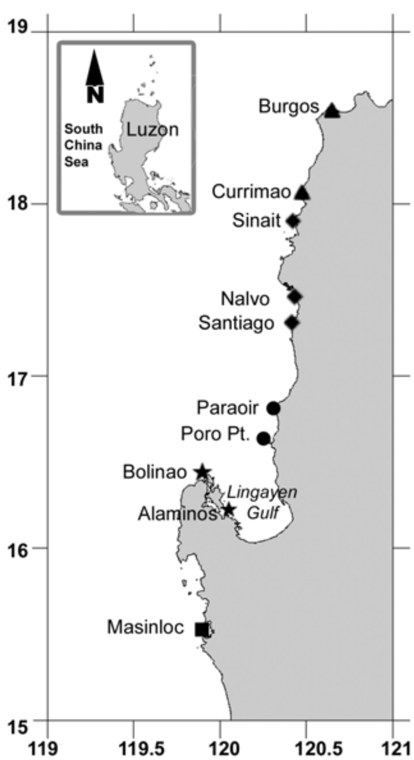

Figure 1. *T. gratilla* monitoring sites in Northwestern Luzon, Philippines. Site legends indicate localities in five provinces: triangle – Ilocos Norte, diamond – Ilocos Sur, circle – La Union, star – Pangasinan, square – Zambales.

Additional surveys were conducted in Poro Pt. in 2006 and 2007 to validate the reported increase of recruits in the area after the initiation of sea urchin grow-out culture. These were compared with densities from a previous survey in December 2003. Monitoring surveys were conducted in three other localities in the Ilocos region (i.e. Sinait, Currimao, Burgos, Fig. 1) from November 2006 to August 2007 in 3 permanently marked sites (2 m x 20 to 50 m), to compare densities and size structure of *T. gratilla* populations.

Results

Variation in Recruitment Strength Among Sites

In Bolinao, >10 individuals 100 m^{-2} was observed for the first time in 2004 since the collapse of the fishery in 1992. The highest density recorded was 460 individuals 100 m^{-2} (of which 80 % were recruits) in Lucero in January 2006 (Juinio-Meñez et al., 2008). Overall, total densities and density of recruits in the three other sites were significantly lower ($p<0.05$) than those in Lucero for the same sampling periods in 2004 to 2007. Notably, there was a positive relationship between the average density of recruits and adults at the four sites during surveys in 2004-2007 (Fig. 2).

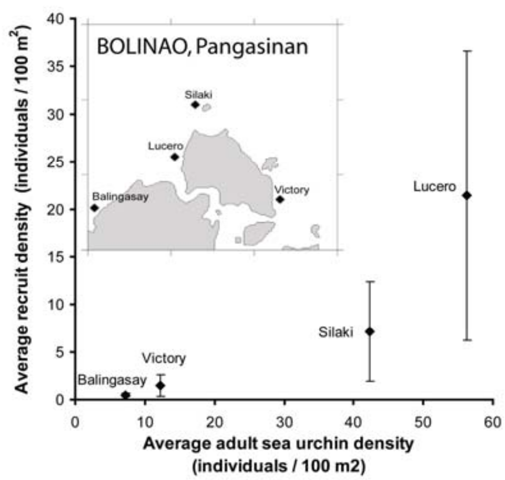

Figure 2. Average density of *T. gratilla* recruits plotted against the adult average densities in Bolinao sites.

A survey in other locations along NW Luzon in early February 2006 showed the presence of recruits in all sites except at the Hundred Island National Park in Alaminos. The modal size class of all sea urchin populations ranged from 3-5 cm TD (Fig. 3). This suggests that the recruits of the year were primarily from larvae, which settled during the previous 3-5 months (September–November 2005), coinciding with the peak of the SW monsoon.

Total density and density of recruits in the sites surveyed in Ilocos Sur, La Union and Zambales during the same period ranged from 10-60 individuals 100 m^{-2}, about an order of magnitude lower than that in Lucero, Bolinao. The harvesting of juveniles for grow-out culture in these areas confounded the estimated densities in Ilocos and La Union. Nonetheless, the density of sea urchins decreased with distance from the grow-out cages in Paraoir and Santiago (data not shown). This observation was consistent with anecdotal accounts of fishers engaged in grow-out culture. In Poro Point and Nalvo, growers also observed higher numbers of juvenile sea urchins near the cages. However no pattern was evident from the field survey results.

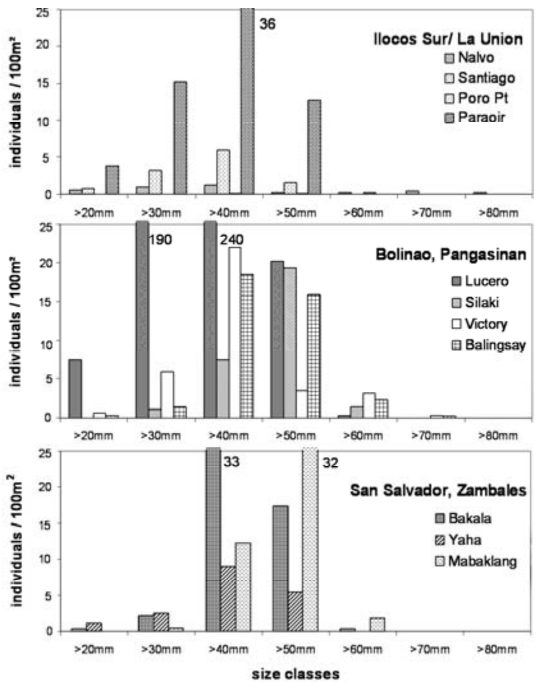

Figure 3. Size frequency distribution of sea urchins in various sites in Northwestern Luzon on January - February 2006.

Monitoring surveys in other sites in the Ilocos region showed significant differences in mean density of *T. gratilla* among the three sites surveyed. Mean densities in Sinait were significantly higher compared to Currimao and Burgos (Table 1). During the November 2006 and February 2007 surveys, early juveniles (10-30 mm TD) comprised about 67% of the total sea urchins sampled in Sinait. Overall, juveniles (< 40 mm TD) were more abundant in Sinait during most sampling months while in Currimao and Burgos, late adults (<70 - >90 mm TD) urchins were more abundant.

Recruitment before and after initiation of grow-out culture in sea cages

Densities of *T. gratilla* increased in Poro Pt., after the initiation of grow-out culture in December 2005 (Fig. 4). Starting September 2006, juveniles comprised 79-83% of the total counts, validating the report of locals on the high incidence of juveniles. Prior to grow-out culture, density of sea urchins in the area was very low. In fact, juveniles for the sea urchin grow-out cages were sourced from a neighboring town (Paraoir). Higher densities of juveniles were found in the monitoring sites inside the embayment. However, there was no positive relationship between abundance of juveniles relative to distance from the grow-out cages up to 50 m.

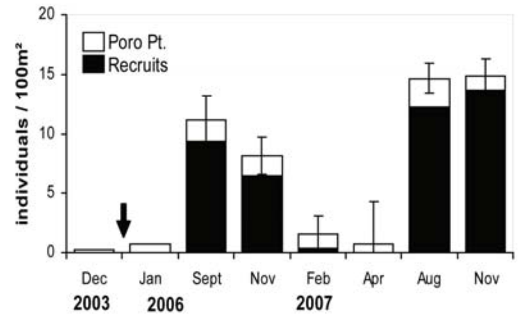

Figure 4. Mean sea urchin density in grow-out site in Poro Pt., La Union. Arrow indicates the start of grow-out culture.

Discussion

The positive correlation in the density of recruits and adults in the four sites in Bolinao, the high incidence of recruits in Lucero and Sinait relative to other sites without sea urchin grow-out culture, and the significant increase in the density of juveniles after the initiation of grow-out culture in Poro Pt. strongly indicate that the aggregation of adults in the grow-out cages enhanced benthic recruitment. In addition, the higher density of sea urchins near the grow-out cages in Paraoir and Santiago during the February 2006 survey validated the anecdotal accounts of fishers engaged in grow-out culture.

Similarly, recruitment strength of *Diadema antillarum* in Barbados was positively correlated with adult densities. Juvenile mortality was low in adult settlement sites and juveniles aggregated in reefs with adult populations. These suggested that regionally dispersed larvae may prefer areas of high adult density (Hunte and Younglao 1988). Compounds from conspecific sea urchins can act as settlement cues for larvae (reviewed in Hugget et al. 2006; Swanson et al. 2006) as described in several benthic marine invertebrates (reviewed in Rodriguez et al. 1993).

Table 1. Overall mean density of *T. gratilla* (individuals 100 m^{-2}) in the three study sites in Ilocos over a ten-month sampling period. Means with the same letters are not significantly different from each other (ANOVA p>0.05, Tukeys HSD test). Standard error values are in the parentheses.

	Nov. '06	Dec. '06	Jan. '07	Feb. '07	May '07	Aug '07	**Mean** (s.e.)
Currimao	17.29	13.97	13.05	19.25	0	80.98	**24.1** [b] (11.7)
Sinait	29.37	49.06	47.08	184.79	70.52	22.18	**67.2** [a] (24.5)
Burgos	7.00	12.00	7.00	16.67	8.33	5.67	**9.4** [c] (1.7)
Mean (s.e.)	**17.88** (6.46)	**25.01** (12.04)	**22.37** (12.47)	**73.57** (55.61)	**26.28** (22.25)	**36.28** (22.85)	

Dworjanyn and Pirozzi (2008) found that *T. gratilla* larvae settled at a higher rate in the presence of live juveniles and their faeces. Settlement near conspecifics provides the advantage of settling in a habitat that can more likely support post-larval growth (reviewed in Pawlik, 1992) and for some species, may provide protection from predation as observed for *Strongylocentritus franciscanus* wherein juveniles were protected by adult spine canopies (e.g. Tegner and Dayton 1977; Tegner and Dayton 1981).

In general, gregarious behavior and high densities in echinoids have been reported to increase fertilization success (Pennington 1985; Levitan 1991; Levitan et al. 1992; Levitan 2004). Likewise, a population genetic study on the red sea urchin *Strongylocentrotus franciscanus* suggests that high population densities are required for successful fertilization (Burton 2003). Clearly, behavior and critical thresholds in density are important considerations in the establishment of marine protected areas (e.g. Dayton et al. 2000). The very high recruitment success of *T. gratilla* in Lucero compared to other sites in Bolinao appears to be due to the synergy of favorable fin scale biophysical factors and local management interventions that enhanced build-up of the spawning population. In particular, the maintenance of the broodstock for the hatchery and juvenile grow-out cages, the strict enforcement of the marine sanctuary and prohibition of harvesting of small-sized sea urchins in the area reestablished adult populations (Juinio-Meñez et al. 2008).

Since the sea urchins in the grow-out cages are not harvested until they are sexually mature (>6 mm TD) and aggregations in the cages may enhance fertilization success, they maybe local sources of larval supply. The marked increase of recruits in Poro Pt. after the initiation of grow-out culture may be attributed to the high entrainment potential in this site. Based on coastal rugosity and wake formation studies, both Poro Pt. and Bolinao were identified to have high entrainment potential that could concentrate larvae locally and facilitate self-recruitment (Magno 2005). Swearer et al. (2002) proposed that positive stock-recruitment relationships over small spatial scales (e.g. 10s kms), which have been documented for species with a wide range of pelagic larval development periods, are indicative of self-recruitment. Moreover, stronger evidence for self-recruitment based on positive stock-recruitment relationships may be derived from the quantification of local recruitment following localized stock enhancement, as evident in the results for Bolinao and Poro Pt. in this study.

On a broader scale, the modal size range for the different populations monitored during January and February 2006 indicate similar temporal patterns in reproduction of populations in the region. The recruits (3-5 mm TD) are likely from spawning events in May-August based on juvenile growth rates and larval duration under culture conditions (Juinio-Meñez and Hapitan 1998). Larval dispersal modeling studies in NW Luzon suggest that *T. gratilla* populations are highly connected by larval transport due to the reversing monsoons (Juinio-Meñez and Villanoy 1995). Population genetic studies using allozyme also provide some evidence of extensive gene flow between *T. gratilla* populations (Malay et al. 2002). Thus, while self-recruitment is highly likely in some sites like Lucero and Poro Point, there is also high larval exchange among populations in NW Luzon.

Given the high potential for larval exchange among localities and the reproductive biology of this species, establishment of a network of marine protected areas and grow-out culture are strategic in conserving larval sinks and sources for *T. gratilla* in the region. Further investigations on fine-scale and meso-scale hydrographic conditions together with genetic studies using DNA markers may further elucidate factors that influence the recruitment dynamics of populations and provide inputs to ensure the sustainability of the fisheries in NW Luzon.

Acknowledgements

The sea urchin population surveys were part of the research projects funded by the U.P. Marine Science Institute, the Department of Agriculture Bureau of Agricultural research (DA-BAR), the Royal Netherlands Embassy (through the Marine Environment and Resources Foundation's SAGIP Lingayen Gulf Project. Monitoring of sea urchins in the other sites in the Ilocos region was part of the research project of HGB and Ruby Jean R. de la Rosa at the Mariano Marcos State University. The University of the Philippines, Department of Agriculture, Bureau of Agricultural Research and the GEF-Local Governance Initiative Project of the U.P. Marine Science Institute provided travel support for MAJM to participate at the 11th ICRS. We are grateful to Ms. Inggat Laya Casilagan for her invaluable assistance in the preparation of the figures, formatting the manuscript, editing and refinement of the manuscript. This is a UPMSI Contribution.

References

Burton RS (2003) Patterns of recruitment in the red sea urchin: a population genetic approach. California Sea Grant College Program. Research Completion Reports. University of California, San Diego. Paper Fisheries 03-01.

Dayton PK, Sala E, Tegner MJ, Trush S (2000) Parks, baselines and fishery enhancement. Bull Mar Sci 66: 617-634

Dworjanyn SA, Pirozzi I (2008) Induction of settlement in the sea urchin *Tripneustes gratilla* by macroalgae, bioilms, and conspecifics: a role for bacteria?. Aquaculture 274: 268-274

Huggett MJ, Williamson JE, de Nys R, Kelleberg SJ, Steinberg PD (2006) Larval settlement of the common Australian sea urchin *Heliocidaris erythrogramma* in response to bacteria from the surface of coralline algae. Oecologia 149: 604-619

Hunte W, Younglao D (1988) Recruitment and population recovery of *Diadema antillarum* (Echinodermata; Echinoidea) in Barbados. Mar Ecol Prog Ser 45:109-119

Juinio-Meñez MA, Bangi HG, Malay MCD, Pastor DS (2008) Enhancing the recovery of depleted *Tripneutes gratilla* stocks through grow-out culture and restocking. Rev. Fish Sci 16:35-43

Juinio-Meñez MA, Villanoy C (1995) Sea urchin recruitment studies for management considerations. Proceedings of the 4th LIPI-JSPS Joint Seminar in Marine Science. Indonesian Institute of Sciences (LIPI) Jakarta, pp.15-20

Juinio-Meñez MA, and Hapitan RM (1998) Mass culture of the Sea Urchin *Tripneustes gratilla*. Trans Nat Acad Sci Tech Philippines, pp308-323

Juinio-Meñez MAR, Macawaris NND, Bangi HGP (1998) Community -based sea urchin (*Tripneustes gratilla*) grow-out culture as a resource management tool. Can Spec Publ Fish Aquat.Sci 125: 393-399

Levitan DR (1991) Influence of body size and population density on fertilization success and reproductive output in a free-spawning invertebrate. Biol Bull 181: 261–268.

Levitan DR, Sewell MA, Chia FS (1992) How distribution and abundance influence the fertilization success in the sea urchin *Strongylocentrotus franciscanus*. Ecology 73: 248–254

Levitan DR (2004) Density-dependent sexual selection in external fertilizers: Variances in male and female fertilization success along the continuum from sperm limitation for sexual conflict in the sea urchin *Strongylocentrotus franciscanus*. Am Nat. 164, No. 3, September 2004.

Magno MM (2005) Estimation of entrainment potential in Philippine coastal waters: the physical consequence of island wakes and eddies. Masteral Thesis, University of the Philippines, p136

Malay MCD, Juinio-Meñez MA, Villanoy CL (2002) Population genetics of the sea urchin *Tripneustes gratilla.* Proc 9th Int Coral Reef Symp 1: 107–112

Pawlik JR (1992) Chemical ecology of the settlement of benthic marine invertebrates. Oceanogr Mar Biol Annu Rev 30:273-335

Pennington JT (1985) The ecology of fertilization of echinoid eggs: the consequences of sperm dilution, adult aggregation and synchronous spawning. Biol Bull 169: 417-430

Rodriguez SR, Ojeda FP Inestrosa NC (1993) Settlement of benthic marine invertebrates. Mar Ecol Prog Ser 97: 193- 207

Swanson RL, de Nys R, Huggett MJ, Green JK, Steinberg PD (2006) *In situ* quantification of a natural settlement cue and recruitment of the Australian sea urchin *Holopneustes purpurascens*. Mar Ecol Prog Ser 314: 1-14

Swearer SE, Shima JS, Hellberg ME, Thorrold SR, Jones GF, Robertson DR, Morgan SG, Selkoe KA, Ruiz GM, Warner RR (2002) Evidence of self recruitment in demersal marine populations. Bull Mar Sci 70:251-271

Tegner MJ, Dayton PK (1977) Sea urchin recruitment patterns and implications on commercial fishing. Science 196:324-326

Tegner MJ, Dayton PK (1981) Population structure recruitment and mortality of two sea urchins (*Strongylocentritus franciscanus* and *S. purpuratus*) in a Kelp forest. Mar Ecol Prog Ser 5:255-268