Co-Management and Bivalve Sanitation for Black Cockles (*Andara* spp.) in Nicaragua

Human Health Impacts of Aquaculture/Experiment/09HHI01UH

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ABSTRACT

Black cockles (*Anadara tuberculosa* and *A. similis*) are an economic mainstay of many poor coastal communities in Latin America with over 2000 Nicaraguans directly benefitting from the harvest alone. Over-harvest and mangrove removal have reduced populations and the current regulatory system has been inadequate to fully address the situation. Beginning in 2006 as part of an integrated coastal management program (SUCCESS/USAID), and continuing under the auspices of AquaFish CRSP, several efforts began with the communities of the Aserradores Estuary to improve shellfish sanitation issues, increase direct revenues to cockle collectors and test whether voluntary, community-managed no-take zones would prove to be a feasible alternative management methods for cockles. Four no-take zones (25.56 ha total) were chosen, managed and monitored with direct participation by cockle collectors. After five years of monitoring, results indicate that *A. tuberculosa* cockle populations increased significantly both inside the no-take zones and in adjacent áreas. Increases were also observed for nearly all size classes for *A. tuberculosa*, but particularly for the smaller size classes, suggesting that the no-take zones resulted in increased recruitment. There was no significant change in *A. similis* populations. Following the success of this model, similar efforts are being pursued with other coastal communities in coordination with government agencies.

INTRODUCTION

Black cockles (*Anadara tuberculosa* and *A. similis*) are the most commonly harvested bivalves in Nicaragua, and are also a common fisheries target along most of the Pacific Coast of Latin America. In general, bivalve fisheries are generally overlooked in terms of fisheries management, with the result that in Latin America, most bivalve population are under considerable stress. This is also linked to issues with mangrove management, the habitat favored by *Anadara* spp. Lack of fully effective management methods and over-exploitation of cockle resources is considered to be an ubiquitous issue throughout Latin America (Mora and Moreno 2007, 2008; Silva and Bonilla 2001; Campos et al. 1990).

Cockle management began in Nicaragua in 1985 with the passing of regulations intended to protect cockle stocks. These regulations established an annual closed season from April 21 to June 15. In 2008, additional regulations were approved that addressed cockle management issues in protected areas, many of which are inhabited by, and still fished by fishers. These regulations have not been effective in maintaining cockle populations, in part because the closed season is not fully respected by fishers. Enforcement is difficult in the remote coastal areas covered by dense mangroves. It also does not necessarily protect cockles during their peak reproductive season. Moreover, coastal inhabitants are driven by the need to collect cockles for daily subsistence and modest income (Cheves 2011); many cockle collectors have few alternatives other than cutting mangroves for firewood.

In an effort to find more effective means of maintaining cockle populations while not adversely affecting the fishers, in 2006 CIDEA began working with the Aserradores community to test alternative management methods, improve shellfish sanitation and increase benefits to collectors with support from the USAID SUCCESS program. Additional CRSP support in 2009 allowed for continuation and expansion of these efforts until 2012. The combined work over the last six years included:

- Water quality testing to determine which areas of the estuary had sufficiently good water quality to allow for harvesting of cockles that are safe to eat (SUCCESS/USAID and CRSP 07IND0UH);
- Testing of field and laboratory depuration methods and rates (CRSP 07IND0UH);
- Development of a solar-powered, community operated depuration center (European Union); and
- Establishment and monitoring of no-take zones to increase cockle populations (CRSP 09HHI01UH).

This report addresses activity #4, which was the focus of the recent investigation (09HHI01UH).

Study site

The Aserradores Estuary is located on the Pacific coast of Nicaragua in the Department of Chinandega, approximately 169 km from the capital of Managua (Figure 1). There are approximately 450 inhabitants in the villages living in 110 houses. The villages are relatively new settlements, being initially populated from neighboring areas by fishers looking for better disembarkation sites. Seventy-four percent of the residents fish, 24% harvest cockles and 1% cut mangroves for firewood (CIDEA 2007). Fishing volume and average fish sizes have declined, and the patterns of good fishing days have also changed. Previously, the fishers could count on at least 15 days of good fishing monthly, now they usually only have good catchs for 2-3 days per month (Reyes 2011). Some tourism is now growing in the area, but the decline in fishing has put increased strains on the cockle fishery.

The Aserradores Estuary has 3,976 ha of mangroves, the majority of which is red mangrove (CATIE 2001). The extensive mangrove forest is used for cockle collection and cutting for firewood.

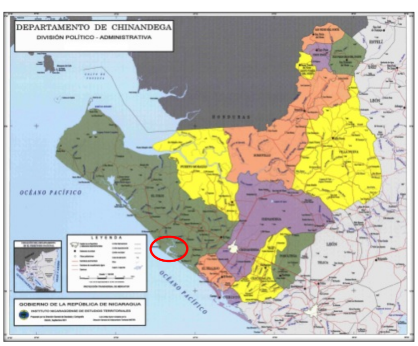

Figure 1. Location of the community of Aserradores in the Department of Chinandega, Nicaragua.

Asseradores was chosen as original test site for this work in 2006 due to the high level of participation in the cockle fishery by its inhabitants. It was also considered a model site due to the generally poor economic status of the community and the multiple stressors on the community, as well as the surrounding habitats. This village exemplifies dozens of other small, coastal villages which depend on natural resources and which are socially marginalized.

The stakeholders who harvest cockles consist of 78 families in two small villages within the area. Ninety-four percent of these villagers depend largely upon cockle harvest. Complete data does not exist for the entire area, but for one of the smaller villages (Teodoro King), there are 311 people, of which 157 are women. The population, like the rest of Nicaragua, is relatively young, with 64.3% of the population being 20 years of age or younger. Women-headed households are common. Only 0.3% of the population is over 65 years of age

MATERIALS AND METHODS

The approach used to develop a co-management system for cockle was based on principles for community participation in coastal management initiatives articulated in Olsen and Ochoa (2004). Work with the Aserradores community began in 2006 with a series of community visits, workshops and general awareness-raising activities. Part of these activities were exercises with the community to chose the estuary areas where the voluntary no-take management zones would be located. At the same time, CIDEA initiated other management activities with the communities such as testing depuration of the cockles to improve human health, and evaluate the possibility of certification to improve the price paid to the collectors.

Initially three no-take zones were selected with the communities, and three years later, another no-take area was added at the suggestion of the community. Currently the total area under management as one of the no-take zones is 26.56 ha (Table 1).

Table 1. Description of no-take zones.

No	Name	Size (ha)	Date declared as a no-take zone
1	Los Tonos	4.22	Sept. 6, 2006
2	Río Viejo	5.95	Sept. 6, 2006
3	Castepe	10.39	Sept. 6, 2006
4	La Chanchera	6.00	April 19, 2009

In choosing the no-take zones with the community, several criteria were used: 1) the sites would be distributed such that no segment of the cockle collecting population was inequitably affected by the prohibition on harvesting; 2) the areas should be easily marked and recognized; 3) historically cockles had been present and harvested there; and 4) were sites not subject to wide flucuations in salinity.

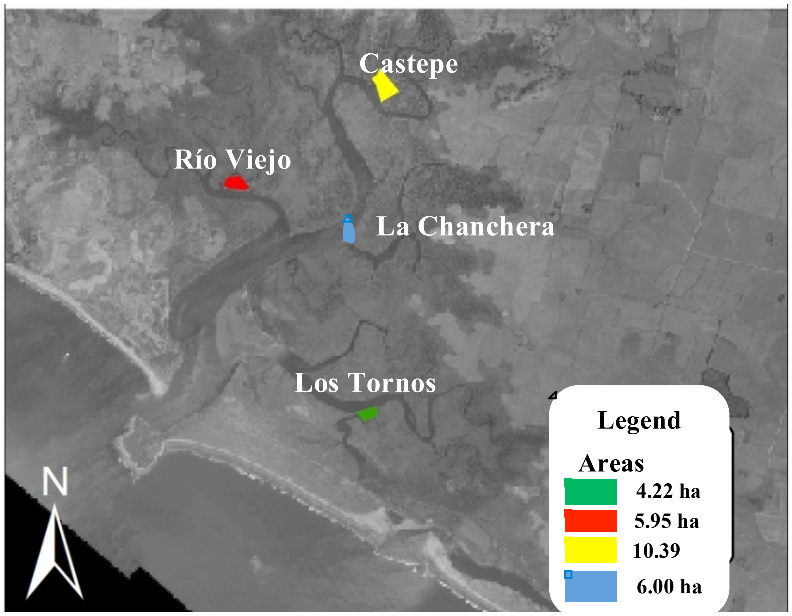

Figure 2. Location of the no-take zones within the Aserradores Estuary.

Each no-take zone was demarcated using painted plastic bottles which were hung in the surrounding mangrove trees above the high tide zone (Figure 3). The markers were periodically replaced. Meetings and visits within the cockle collecting villages were held to assure that everyone was familiar with the areas, the voluntary rules on collection and the potential benefits to the communities. General educational awareness presentations were also given.

Figure 3. Painted plastic bottles were used to mark the boundaries of the no-take zones.

To determine the cockle population density, a stratified sampling method was used. Fourteen 14 points within the estuary were selected for sampling. Six of these were located at points along the principal branch of the estuary (harvested areas) and two in or near each no-take zone. Of the latter two, one was within the boundaries of the no-take zone and one was located 100 meters from the no-take zone. Sampling in the latter was of interest to determine if a possible spill-over effect would result from the management of the no-take zones. Coordinates of the sampling sites are presented in Table 2 and a map of the sampling sites is shown in Figure 4. For each sampling event, three replicate plots (4 m^2 each) within each site were sampled. The participation of the cockle collectors, including children, was essential for the sampling as cockles are difficult for non-experienced people to find, given their habit of living amongst mangrove roots. Even with this expert help, population numbers may be under-counted.

Table 2. Sampling sites to determine population densities.

No	Designation	Coordinates	
		X	Y
1	Point No.1	463656	1396888
2	Point No.2	464457	1396355
3	Point No.3	465273	1398249
4	Point No.4	465895	1397454
5	Point No.5	465072	1398514
6	Point No.6	465145	1398738
7	Los Tornos inside (within no-take zone)	465700	1394100
8	Los Tornos outside (adjacent to no-take zone)	465600	1394200
9	Río Viejo inside (within no-take zone)	463685	1397411
10	Río Viejo outside (adjacent to no-take zone)	463946	1397273
11	Castepe inside (within no-take zone)	465932	1398943
12	Castepe outside (adjacent to no-take zone)	465373	1399086
13	La chanchera inside (within no-take zone)	466243	1396571
14	La Chanchera outside (adjacent to no-take zone)	465845	1396458

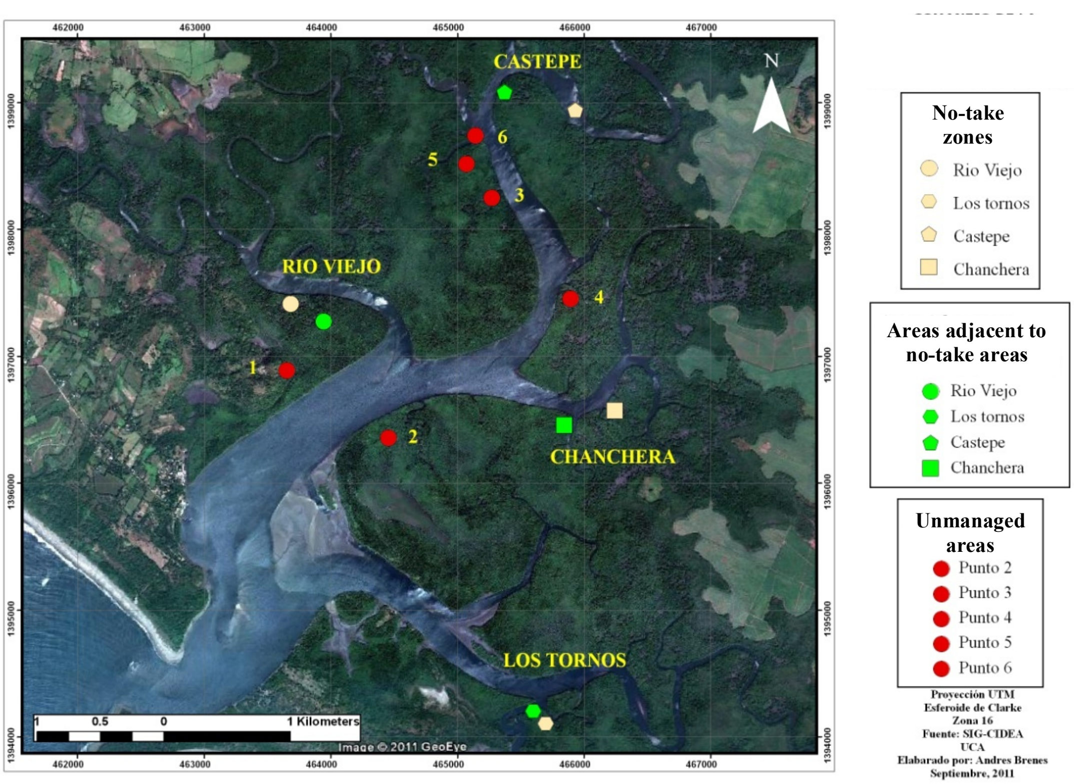

Figure 4. Map of the sampling sites within the Aserradores Estuary. The no-take zones are indicated, as well as the sampling sites that are adjacent to the no-take zones and sampling areas which were not under management, i.e. subject to uncontrolled cockle harvest.

Cockles (*Anadara tuberculosa* and *A. similis*) were then removed from each of the sample sites. Three replicate samplings were taken at each of the 14 sample sites and each sample comprised an area of 4 m^2. Between 2006 and 2011, eight sampling periods occurred. These represented months 0 (initiation of the trial), 6, 12, 23, 30, 49, 55 and 59 months. Data collected included the number of cockles at each site, and length (DVM) and weight. Data was analyzed using SPSS software for ANOVA, box plots and frequency histograms.

RESULTS

Population Densities

At the establishment of the no-take zones, minimum and maximum densities for both species were 1.42 ± 0.45 and 5.17 ± 0.45 cockles/m^2 , respectively, and the mean was 3.07 ± 0.45 cockles/m^2. For *A. tuberculosa*, the minimum density was 1.33 ± 0.37 cockles/m^2 and the maximum was 4.42 ± 0.37 cockles/m^2. For *A. similis*, the minimum density was 0.08 ± 0.08 cockles/m^2 and the maximum was 0.75 ± 0.08 cockles/m^2 (Table 3).

Table 3. Cockle densities at the beginning of the study. Minima and maxima are the average for each parameter among all the sites.

Population densities at the beginning of the study (cockles/m^2)	***A. tuberculosa* and *A. similis***	***Anadara tuberculosa***	***Anadara similis***
Initial minimum population density	1.42 ± 0.45	1.33 ± 0.37	0.08 ± 0.08
Initial maximum population density	5.17 ± 0.45	4.42 ± 0.37	0.75 ± 0.08
Initial mean population density	3.07 ± 0.45	2.71 ± 0.37	0.37 ± 0.08

Fifty-nine months after establishment of the no-take zones, the combined average densities for the two species had increased from 3.07 ± 0.45 to 8.02 ±1.08 cockles/m^2, representing an increase of 4.95 cockles/m^2. The minimum and maximum densities were 1.92 ± 1.08 cockles/m^2 and 19.75 ± 1.08 cockles/m^2 for both species. The final mean densities for the two species was 7.62 ± 0.97 cockles/m^2 (*A. tuberculosa*) and 0.40 ± 0.12 cockles/m^2 (*A. similis*) (Table 4).

Table 4. Cockle densities at the end of the study (after 59 months of management). Minima and maxima are the average for each parameter among all the sites.

Population densities at 59 months after initiation of the study (cockles/m2)	***A. tuberculosa* and *A. similis***	***Anadara tuberculosa***	***Anadara similis***
Final minimum population density	1.92±1.08	1.83±0.97	0.00±0.12
Final maximum population density	19.75±1.08	19.08±0.97	1.25±0.12
Final mean population density	8.02 ± 1.08	7.62±0.97	0.40±0.12

ANOVA analysis show that population increases for *A. tuberculosa* were significantly higher, but changes for *A. similis* densities over the 59 months of management were not significantly different (Table 5).

Table 5. ANOVA results for cockles densities at zero and 59 months.

		Sum of squares	df	Mean square	F	Sig.
Density (cockles/m^2) *Anadara tuberculosa*	Between groups	258.195	5	51.639	4.296	.002
	Within groups	769.340	64	12.021		
	Total	1027.535	69			
Density (cockles/m^2) *Anadara similis*	Between groups	.393	5	.079	.470	.797
	Within groups	10.699	64	.167		
	Total	11.092	69			

Given that changes in population densities over the 59 months of management did not change significantly for A. similis, the following discussion presents the detailed results for A. tuberculosa only.

The box plot for A. tuberculosa densities at all sampling sites shows some flucuations in the average density over the years between 2006 and 2011. The overall trend is an increase in densities. The fourth no-take area, “La Chanchera”, which was established in 2009, always had population densities higher than at the other sampling points (Figure 5).

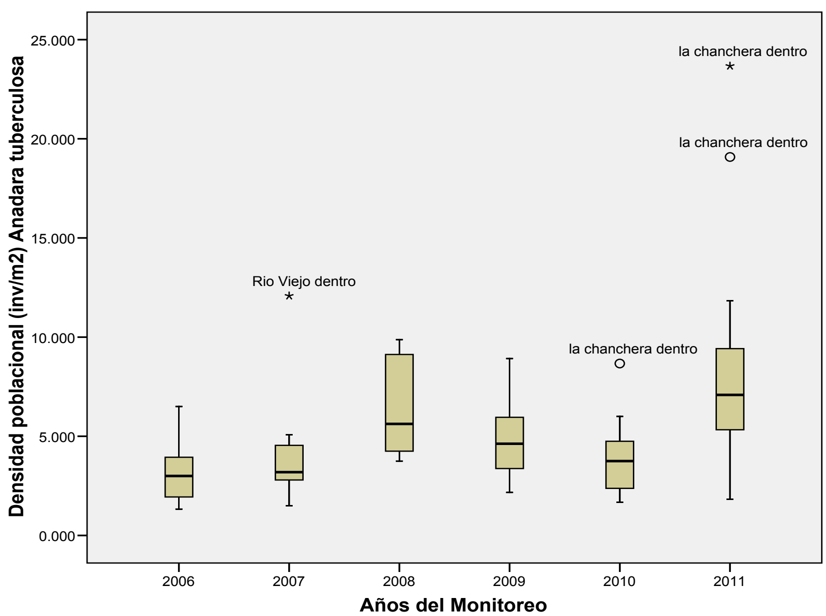

Figure 5. Box plot for *A. tuberculosa* densities combined for all sampling points.

The densities for the sampling points within the no-take zones and the adjacent areas, shows a pattern similar to the densities considered for all sampling points (Figure 6).

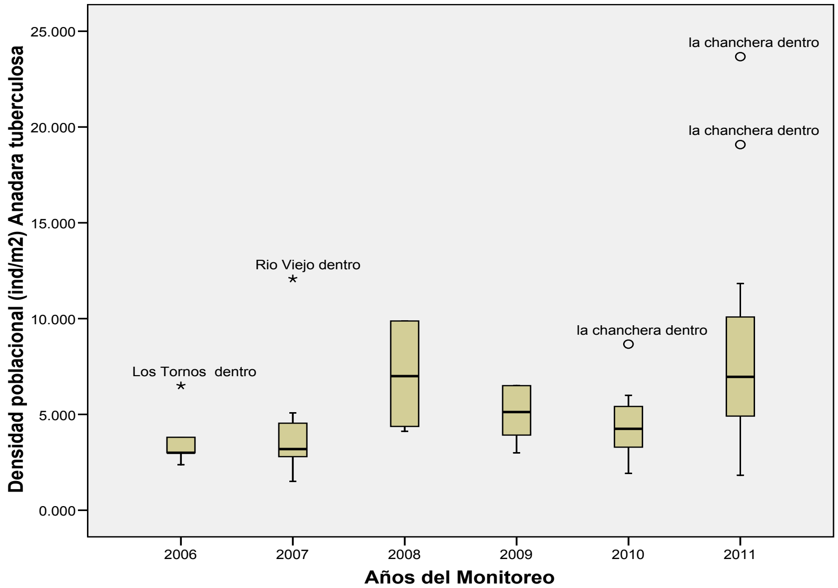

Figure 6. Population densities for *A. tuberculosa* for sampling stations within the no-take zones and the adjacent areas.

ANOVA results (Table 6) also indicate that the population densities for *A. tuberculosa* inside the no-take zones and the adjacent areas did not differ significantly. Figure 7 shows the densities for the sampling stations within the no-take zones, while Figure 8 presents the results from sampling points from areas where harvest was permitted.

Table 6. *A. tuberculosa* densities within the no-take zones and at adjacent sites.

	Sum of squares	df	Mean square	F	Sig.
Between groups	164.151	5	32.830	2.056	.090
Within groups	670.728	42	15.970		
Total	834.878	47			

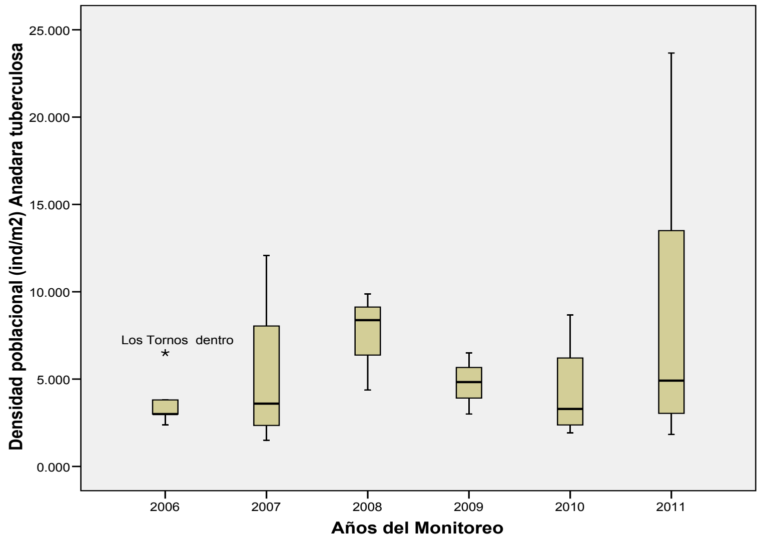

Figure 7. *A. tuberculosa* population densities in the no-take zones.

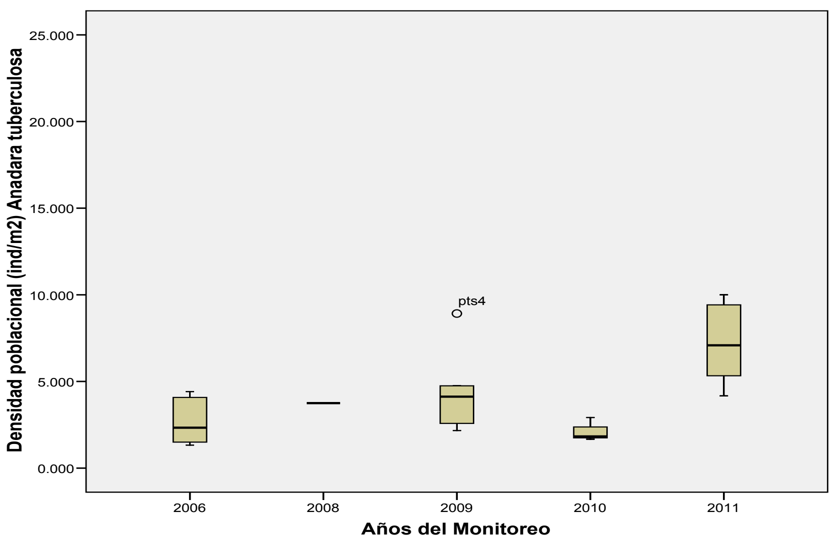

Figure 8. *A. tuberculosa* population densities in the areas where harvest was allowed.

At the end of 2011, the mean population density for all sites increased significantly (Figure 9, blue histogram). The highest individual counts encountered among the sites also increased from 11 to 22 cockles, although flucuations in maximum counts varied over time (Figure 9, green trend line).

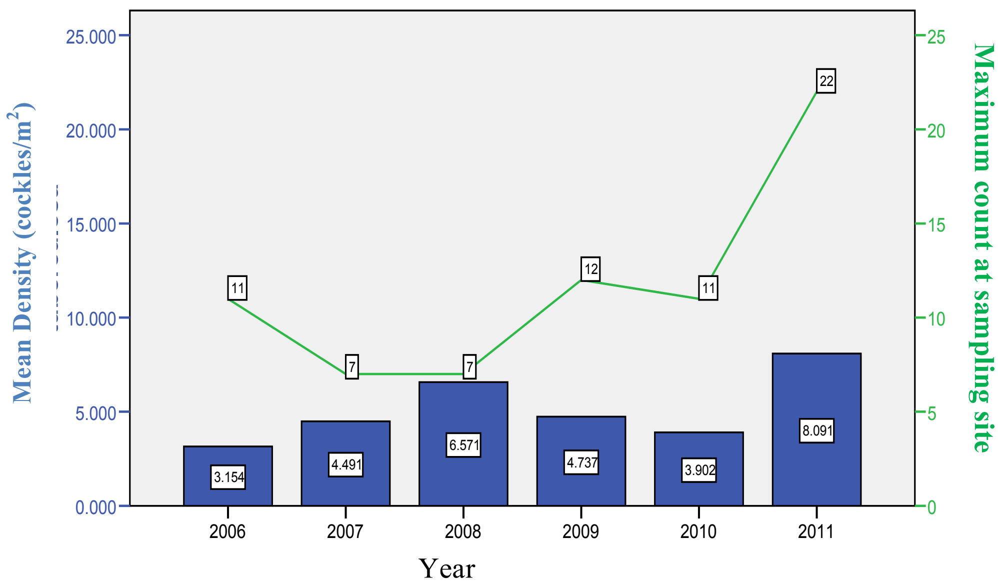

Figure 9. Mean densities for all sampling sites (in blue histogram) and maximum count at any sampling site during the sampling period (green line). In the case of years where two samplings were conducted, results are combined to represent the average for that year.

Population structure

According to the distribution histogram, there was an increase in all size classes, but particularly for the size classes between 5 and 50 mm for *A. tuberculosa* (Figure 10).

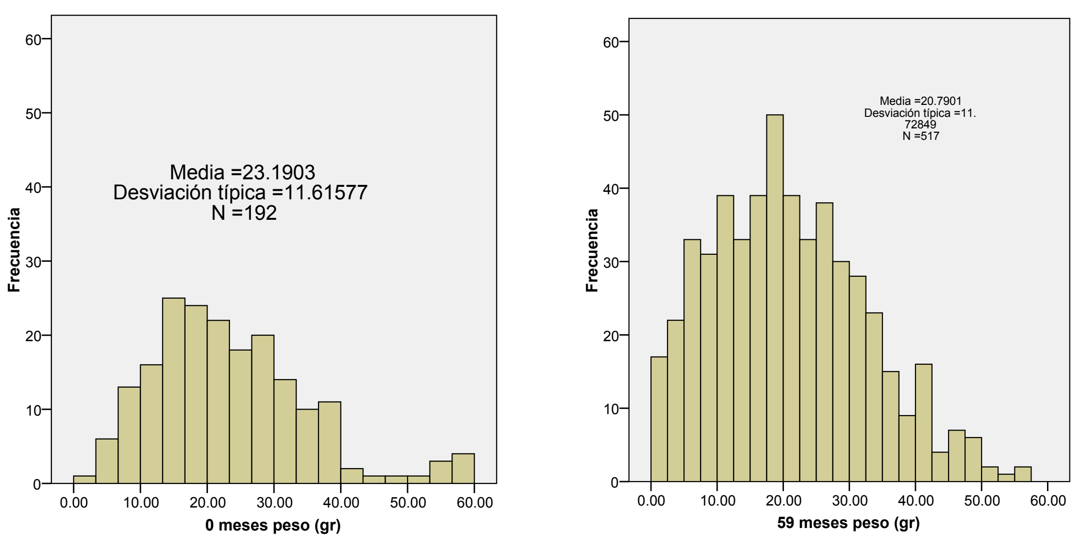

Figure 10. Size class distributions at months 0 (left) and 59 (right) for *A. tuberculosa*.

DISCUSSION AND CONCLUSION

Information on cockle population densities is not available for the Aserradores Estuary for periods prior to initiation of this research. Arrechavala and Estrada (2004) found population densities for cockles at six Nicaraguan estuaries ranged from 0.005 to 0.82 cockles/m^2 for *A.tuberculosa* and 0.002 to 0.6 m^2 for *A. similis*. Silva and Bonilla (2001) found that *A. tuberculosa* densities in Costa Rica were 0.8±0.1 to 1.2±0.1 cockles/m2. Densities in Ecuador were reported as 3.74±0.72 ind/m^2 (Mora and Moreno 2006).

Since cockle densities for both species increased from 3.07 ± 0.45 cockles/m^2 in 2006 to 8.02 ± 1.08 cockles/m^2 in 2011, representing an increase of 4.95 cockles/m^2 in 59 months, this suggests that the no-take zones were effective in protecting the cockle population and led to an increase in population densities. The final results also compare favorably to the cockle densities found in other heavy fished estuaries in Nicaragua, Costa Rica and Ecuador. For the species *A. tuberculosa*, increases in densities over the 59 month period led to mean final densities (19.75 cockles/m^2) that were also much higher than those reported elsewhere. While *A. similis* populations did not display a signficant change in population densities, the densities at least did not decrease, which may have been a possibility considering the intensity of the cockle fishing in the area. One issue with both the lack of significant increases of *A. similis* over the 59 month period, as well as the flucuations in densities between years may be sampling error. Cockle distribution tends to be patchy. They can also be difficult to find and although most of the cockle collectors participating in the monitoring tended to participate throughout the five years, there could have been some change in either the expertise or level of effort among the collectors.

The differences in population densities for *A. tuberculosa* and *A. similis* at the final stages of this study are not dissimilar to differences in populatio ratios for the two species encountered in other studies. In Ecuador the ratio of *A. tuberculosa* to *A. similis* was found to range from 3.5:1 to 4:1 (Mora and Moreno 2006). The two species also occupy slightly different habitat types within the estuary. *A. tuberculosa* tends to be found in clay-like soil under *Rhizophora mangle* roots at a depth between 5-30 cm while *A. similis* is found between 15 and 50 cm in soft substrates in subtidal areas, often in open areas not covered by mangrove (Mora 1990; Fisher et al. 1995; Borda and Cruz 2004). *A. similis* may therefore be more subject to harvest and thus may need additional no-take zones to fully protect this species.

The highest counts from any sampling site at each sampling period increased from 11 in 2006 to 22 in 2011. This information is particularly persuasive to cockle collectors since their livelihoods depends on being able to readily locate patches of cockles with high counts in order to improve the efficiency of collection, particularly since collection time is limited by the tides. The ability to locate and collect large numbers of cockles also affects the cost per unit for collection since collectors may rent canoes to access some areas. Collectors reported that even at the first sampling period (6 months), their perception was that more cockles, particularly small cockles, were found in and around the no-take zones.

Previous studies suggest that *Anadara* cockles may reproduce up to three times yearly (Garcia et al. 2008; Maldonaldo 2005). Reproductive size is believed to be between 23.2 and 26.2 2 mm (Ampie and Cruz 1988) with the maximum size of 81 mm being reached in five years (de Madrigal 1980; Campos et al 1990; Borda and Cruz 2004) for *A. tuberculosa*. The legal minimum size for the two species is 40 mm for *A. similis* and 50 mm for *A. tuberculosa*. Within the five year period of this study, at least two generations of cockles should have reached sexual maturity. The increases in the size classes under 50 mm may be reflecting increased recruitment and growth of the smaller size classes. The lack of change in size classes above 50 mm and the lack of very large cockles, may indicate the continuing intensity of fishing for larger, legal sizes.

An important component of this work was the collaboration with other institutions and communities in order to replicate this work if the establishment of no-take zones as a management method proved to be successful. UCA collaborated closely with INPESCA, FUNDAR, MARENA, UNAN-León to conduct the research and to raise awareness of cockle management issues and approaches in other coastal communities. This included several efforts not originally included in the planned work, but which will contribute signficiantly to improved management of bivalve sanitation and fisheries management. UCA is now developing a solar powered depuration center in the Aserradores community. Government agencies and other communities are also now evaluating the use of no-take zones as a legally acceptable management method. Additionally, the institutions involved in this work also collaborated to develop a strategic management and development plan (2012-2016) for the cockle sector. Results from this work were presented at numerous community workshops, and two regional workshops (Cental America and Mexico) supported by CRSP. The latter is described in the final technical report for CRSP investigation 09HHI02UH.

This work demonstrates that this co-management method based on no-take zones can be an effective alternative management method. The successful implementation of this approach is only effective when both the community and the regulatory agencies fully engage with, and participate in the efforts. Long term sponsor support is also key. Time is needed to lay the ground work to implement no-take zones, as well to detect changes in populations densities and structure that are not only scientifically valid, but are observable to the communities supporting the efforts and sacrificing some of their gathering areas. Continual efforts to keep the community informed as to the results is also important to maintain their interest and support.

LITERATURE CITED

Arrechavala, C. and Estrada, R. 2004. Evaluación ecológica y bromatológica de las especies *Anadara tuberculosa* y *Anadara similis* en los departamentos de León y Chinandega. Universidad Centroamericana. Tesis.

Ampie, C. and Cruz, A. 1988. Tamaño y madurez sexual de *Anadara tuberculosa* (Bivalvia:Arcidae) en Costa Rica.

CATIE. 2001. Estrategia para el Desarrollo y la conservación de la zona costera municipio El Viejo, Nicaragua/CATIE, Alcaldía Municipal El Viejo, Instituto de Desarrollo Rural, Ministerio de Ambiente y Recursos Naturales. Turrialba, CR. 98 p Serie técnica No 321.

Campos, J. Founier, M. Soto, R. (1990) Estimación de la población de *Anadara tuberculosa* en Sierpe – Terraba Costa Rica. Rev Biol. Trop. 38: 477-480

Borda, C.A. and R. Cruz. 2004. Crecimiento y tasas de mortalidad del bivalvo *Anadara tuberculosa* (SOWERBY, 1833) en el Pacífico Colombiano. Rev. Invest. Mar. 25(3):177-184.

Centro de Investigación de Ecosistemas Acuáticos (CIDEA). Universidad Centroamericana. 2007. Linea de base y trayectoria del cambio, comunidad de Aserradores. Municipio de El Viejo. Managua, Nicaragua. 40 pp.

Centro de Investigación de Ecosistemas Acuáticos (CIDEA). Universidad Centroamericana. 2005. Estudio de mercado de moluscos, ostras, mejillones y almejas en Centroamérica y del mercado interno de conchas negras en Nicaragua. Managua, Nicaragua.

Cheves, C. (15 de Abril de 2011). Las conchas negras tienen rostro de pobreza extrema. (results of interview conducted by Nelvia Hernandez.).

Mora, e. and J. Moreno. 2006. Estado de la pesquería del recurso conchas (*Anadara tuberculosa* y *A. similis*) en la Costa Ecuatoriana. Instituto Nacional de Pesca. Ecuador.

García, F., A. Haro, A. García, and C. Marcial, F. Villalejo and S. Rodríguez. 2008. Ciclo reproductivo de *Anadara tuberculosa* (Sowerby, 1833) (Arcidae) en Bahía Magdalena, México. Revista de Biología Marina y Oceanografía 43(1): 143-152.

Hernández, N., A. Saavedra and C. Hernández. 2011. Diagnóstico sobre el estado de aprovechamiento del recurso conchas negras (*Anadara tuberculosa* y *Anadara similis*) en la costa pacífica de Nicaragua. Instituto CIDEA, Universidad Centroamericana.

Hernández, C. 1992. Diagnosis del recurso conchas de la región II del Pacífico de Nicaragua UNAN. León Nicaragua, 7 pag. No publicado.

Mora, E. and J. Moreno. 2007. Abundancia y estructura poblacional de *Anadara tuberculosa y A. similis* en las principales áreas de extracción de la costa Ecuatoriana. Informe técnico INP.

Mora, E. and J. Moreno. J. 2008. Variación temporal de las densidades de *Anadara tuberculosa* y *A. similis* en los ecosistemas de manglar de la costa ecuatoriana. Informe Tecnico

Maldonado, J. 2005. Aspectos Biológicos y Pesqueros de la Concha Prieta (*Anadara tuberculosa*) en Puerto El Morro entre septiembre y diciembre de 2005. Instituto Nacional de Pesca Ecuador. Investigación de los Recursos Bioacuáticos y su Ambiente.

Olsen, S. and E. Ochoa. 2004. Marco Metodológico y conceptual para la Planeación e Implementación del Manejo de Ecosistemas Costeros. Centro de Recursos Costeros Universidad de Rhode Island y Fundación EcoCostas. Guayaquil.

Rendón, M., E. Suárez and M. Mejía. date unknown. Manejo sustentable y comercialización de concha prieta en cautiverio en Puerto el Morro (Provincia del Guayas), para su exportación hacia España. Facultad de Ciencias Humanísticas y Económicas. ESPOL.

Reyes, J. 2011. (20 septiembre 2011). Owner of a cockle consolidation center in Aserradores. Personal Communication. (Interview by Nelvia Hernandez).

Resolución No. 243-2009. Reglamento técnico RTCA 67.04.50:08. Centroamericano. Alimentos. Criterios microbiológicos para la inocuidad de alimentos.

Silva, M. and R. Bonilla. 2001. Abundancia y morfometría de *Anadra tuberculosa* y *A. similis* (Mollusca Bivalvia) en Manglar de Purruja, Golfo Dulce, Costa Rica. Centro de Investigación en Cinecias del Mar y Limnología (CIMAR), Universidad de Costa Rica. San José.

Villalobos, C. and A. Baez. 1983. Tasa de crecimiento y mortalidad de *Anadara tuberculosa* (Bivalvia: Arcidae) en dos sistemas de cultivo en el Pacífico de Costa Rica.

Ville, C. W. Walkerand F. Smith. 1990. Invertebrados superiores. En: Biología. México, Editorial McGraw- Hill.