Exploring Relationships Between Abundance of Spiny Lobster and Environmental Variability in the San Andres Archipelago: Implications for Fisheries Management

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ABSTRACT

This study presents the results obtained by looking at the relationship between the abundance of the spiny lobster trap fishery and the satellite information of several environmental parameters within the San Andres archipelago from 2003 to 2006. Lobster abundance was obtained from an updated database containing more than 32.000 data entries having additional detailed geo-spatial of the lobster trap fishery pooled at weekly basis given voluntarily by the fishing captains from their log-books. Global scales environmental information on sea surface temperature, sea surface temperature anomaly, wind speed and sea surface height was obtained by downloading processed products from the Naval Research Laboratory web page (http://www.7320.nrlssc.navy.mil). The correspondent moon phase was also integrated to the database. Unfortunately, the comparison will combined information at two different scales, 10's of km for abundance and 100's of km information allowing the establishment of general trends rather than a precise relationship. GIS processing utilized ILWIS (Integrated Land and Water Information System) Vs 3.2 to obtain pixel values of the different parameters at each satellite image whiting the sub-set of the study area. Correlation coefficients, linear and multiple regressions were estimated using Microsoft Office ®Excel 2003 and Minitab*TM* *Vs.* 13.1. at the spatial and temporal scales. Lobster density identified peaks of maximum values in particular areas during particular weeks/months, but not significant relationship was determined to explain the abundance pattern with any environmental parameter. Perhaps, indicating occurrence of special population events. For instance maximum abundance in 2005 happened one-two weeks prior the influence of Hurricanes Wilma.

KEY WORDS: Lobster abundance, environmental influences, GIS use in fisheries.

Explorando las Relaciones entre la Abundancia de Langostas Espinosas y la Variabilidad Ambiental en el Archipiélago de San Andrés: Implicaciones de Manejo Pesquero

Este estudio presenta los resultados obtenidos al examinar las relaciones entre las abundancias de langostas pescadas con nasas y la información satelital de varios parámetros ambientales en el Archipiélago de San Andrés entre 2003 y 2006. Las abundancias de langostas se obtuvieron de una base de datos conteniendo más de 32.000 entradas con información geoespacial detallada, agrupada por semanas, y digitalizada de las bitácoras de los capitanes de pesca entregadas en forma voluntaria. La información ambiental de escala global de la temperatura superficial del mar, anomalía de temperatura, velocidad del viento y altura de la ola superficial fueron bajadas como productos procesados del portal del Laboratorio Naval de investigaciones (http://www.7320.nrlssc.navy.mil). La fase lunar correspondiente también fue integrada posteriormente. Desafortunadamente, la comparación combinara información a dos escalas, décimas de kilómetros para la abundancia y centésimas de kilómetros para lo ambiental, lo que permitirá establecer tendencias generales y no relaciones estadísticas precisas. El procesamiento para obtener los valores de los parámetros por píxel se hizo con el programa ILWIS vs. 3.2 (sistema integrado de información terrestre y acuática) para cada imagen de satélite en la sección del área de estudio. Los coeficientes de correlación, regresión linear y regresión múltiple fueron estimados utilizando Microsoft Office ®Excel 2003 y MinitabTM Vs. 13.1. a diferentes escalas espaciales y temporales. La densidad de langostas identifico picos en áreas particulares o en semanas/meses particulares, pero no se encontraron relaciones significativas para explicar los patrones de abundancia observados. Probablemente, indicando la ocurrencia de eventos poblacionales especiales, la influencia de los Huracanes Wilma y Beta con máxima abundancias en el 2005.

PALABRAS CLAVES: Abundancia langosta, factores ambientales, SIG y pesquerias

INTRODUCTION

The spiny lobster (*Panulirus argus*) fishery has been considered as the most valuable stock within the Caribbean Sea, and yet still sparse information has become available to understand its variability and abundance trends. The work presented here combined detailed log book information kindly supply by industrial fishers to the fisheries management personnel as a result of increasing collaborative process generated more than a three years ago, which in turn resulted in increasing trust between the two sides.

The main objective was to look at possible relationship between the lobster densities and the environmental parameters obtained from remote sensed products available online. Satellite information between 2003 and 2006 and fishery dependent data from the trap industrial activity were examined to determine, if some, spatial or temporal patterns. The study will combine information at two different spatial scales, therefore introduce an error source, which is expected to be constant and have undetermined effects, but it will allow to have the first approximation towards the inclusion of environmental factors into the fisheries management within the Seaflower Biosphere Reserve.

Previous unpublished studies working only with the log book data were able to establish a negative trend in this fishery, reducing lobster densities three times in just 15 years (Prada *et al* 2004, Prada *et al* 2005). Progressive restrictions on the lobster fishery has allowed to apparently keep it at the full exploitation levels, but risk of over-fishing will increase if additional environmental factor are continue to be ignored.

STUDY AREA

Located in the Western Caribbean, but belonging to Colombia, the San Andres, Providencia and Santa Catalina Archipelago is found between 11˚ 30' to 16˚ 30' N and 78˚ 28' to 82˚ W. The Archipelago includes three small inhabited islands - San Andres (SAI) and the island pair of Old Providence and Santa Catalina (PVA), as well as seven uninhabited cays and coral banks, with a total insular area of 57 km^2 and a marine area of around 250,000 km^2 surrounded by deep and oceanic environments (as deep as 5000 m). The archipelago also includes a section of the Nicaraguan rise, known as Green Moon ('Luna Verde') or 'La esquina' and numerous uncharted seamounts.

Atolls are line up in a north-northeastern direction and vary in shape, extension and separation among them (can be hundreds of kilometers apart) and have distinct habitats and productivity rates, thus conferring each one with unique ecological characteristics, despite their similarities. In general, reef complexes in the archipelago are characterized by the presence of barrier reefs and shallow and deep fore-reef on their windward side, a central reef lagoon with coral reef patches and slopes with different steepness on their leeward side. Around the archipelago, there is a predominantly westward flow that mixed with an opposite one present in the south-west section of the Caribbean, thus generating the Colombia-Panama gyre. This gyre is present year round with a mean velocity of 1 m/s (Andrade 2001) and might be the regional mechanism for larval retention and perhaps responsible for the high abundances and diversity seen in most archipelago's reefs. Despite not having detailed bathymetry, it is expected that the presence of corals as well as sea mounts (elevations) and trenches (depressions) probably play a role in generating highly-variable small-scale circulation patterns, thus maintaining variable and high marine productivity (Gonzalez 1987).

METHODS

In this work, the mean lobster density of the San Andres archipelago between 2003 and 2006 was estimated on a weekly basis from information registered in the captains log books, which identified the number of lobsters got in a trap the line and its georeference (initial and end position). A total of 33,386 entrances from 53 boats utilizing lines of traps at industrial levels were obtained. The lobster industrial fleet uses around 2,500 traps, which are organized in lines of 100 traps each, occupying around 1 km^2 in length.

Comparative environmental data were downloaded from global images already processed and available at two facilities. Data from 2003 to 2005 were got from the US Naval Research Laboratory (http://www.7320.nrlssc.navy.mil), while data from 2006 were obtained from the NOAA Coral Reef Satellite (http://coralreefwatch.noaa.gov/satellite/index.html). Among the environmental parameters it was possible to get:

i) SST or sea surface temperature (^oC);
ii) SSH or sea surface wave height (cm); c
iii) WS or mean wind speed (m/sec); and
iv) SSA or sea surface temperature anomaly.

Data was obtained from the Jeason altimeter on Modas, Modas NIF and FIR, and from Modis Aqua with the sensors NOAA GOES-10, GOES-12, NOAA POES-17 and POES-18. Global images had pixel values within 100 km^2.

GIS analysis were performed using ILWIS Academic version 3.2 (The Integrated Land and Water Information System), using two different techniques. On one hand, image was geo-referenced with the tie-points technique, and on the other hand parameter value was estimated from the pixel reflectance value and the color separation technique. The GIS analysis was done only for a subset of the imagery containing the area covered by the San Andres archipelago, which was created with the submap software routine. ILWIS was also used to combine the lobster density data with the environmental data through the common column of week number, as the consecutive identifier.

Statistical relationships among variables were explored using Microsoft Office ®Excel 2003 and Minitab™ Statistical software version 13.1, after verification of assumptions. Single and multiple correlations and regressions were performed. Data was analyzed within five sub-areas accordingly with archipelago's atolls or fishing zones: Green moon, Cluster, Queena, Nqueena and Serranilla (Table 1, Figure 1).

RESULTS

As presented in Table 2, the lobster density within the archipelago between 2003 and 2006 averaged 4,4 ind/25 traps, with the most fished zone found in the named green moon (3.7 ind/25 traps) and with higher values in remote and deeper zones named as Cluster and Serranilla being 5.5 ind/25 traps. However, no distinct pattern was observed when looking at annual variations.

The overall lobster densities plotted against the four environmental parameters analyzed is presented in Figure 2. The figure illustrates a weak tendency of higher densities with SSA and SST and more variable behavior with SSH and WS.

Tabla 1. Effective area fished (km^2) discriminated by zone. Area is 1 km^2 buffer around the GPS initial deployment site. n = 33.348.

Zone	2003	2004	2005	2006	Mean area	% use
Green Moon (Colombian section Nicaraguan rise)	5728	10789	7528	3126	6792.8	81.4
Cluster	708	1133	863	12	679.0	8.8
Queena	972	1291	673		978.7	8.1
N Queena	50	182	75		102.3	0.9
Serranilla		52	197		124.5	0.7

Table 2. Annual variation in lobster density (ind//25 traps) discriminated by fishing zone. Values in parenthesis represent one standard deviation.

Lobster/ 25 traps	Green Moon	Cluster	Queena	Nqueena	Serranilla
2003	3.94 (4.2)	8.58 (13.3)	4.64 (4.7)	3.34 (3.2)	
2004	2.86 (3.0)	4.73 (5.0)	3.76 (3.7)	4.40 (3.9)	6.36 (3.3)
2005	3.60 (4.2)	3.76 (3.0)	1.94 (2.2)	4.45 (2.1)	4.37 (2.6)
2006	4.20 (3.8)	5.00 (3.0)			
Average	3.7	5.5	3.4	4.1	5.4

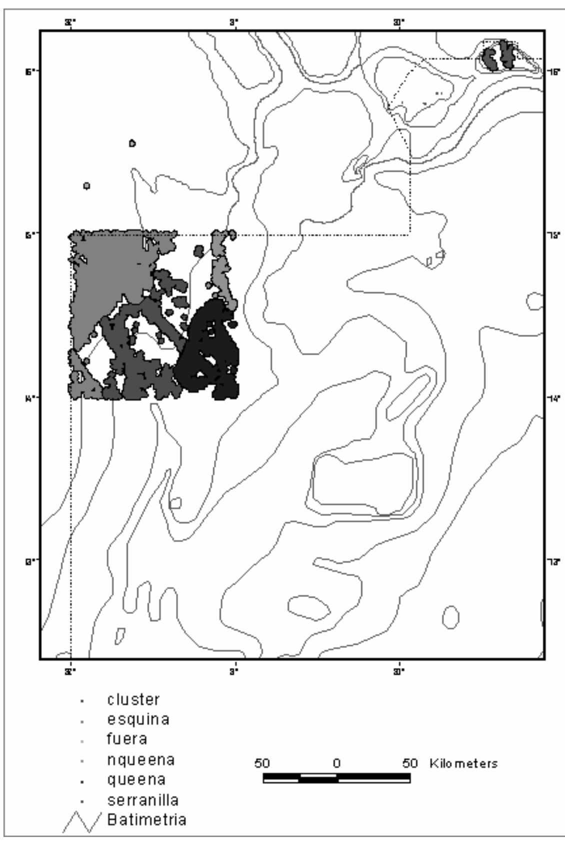

Figure 1. Map of the study area.

The tendency can be see clearly only when lobster densities is compared at weekly basis and by fishing zone. Figure 3 shows how with higher densities values were associated with shifts in SST or higher values in SSA observed in August, October and January, and how they varied across the fishing zones. Lower densities were found at the end of June and July.

Interesting was to find sporadic larger peaks in lobster density (98.3 to 16.8 ind/25 traps) coinciding with the pass of Hurricanes or cold fronts during the three years of observation (Table 3). Perhaps lobsters can sense changes in the water parameters, migrate and then got caught in the traps. However, not all maximum densities were associated with this effect, thus denoting the complexity of the relationship. Interesting was to observe more peaks of high lobster densities in 2003 than in 2005, perhaps indicating progressive reduction in the population abundances.

Apparent tendencies could not be corroborated by statistics tests. In the case of SST, higher lobster densities were detected between 28 and 30 ˚C but Pearson correlation coefficient was only 0.14.

The SSH for larger densities was found between 30 and 35 cm, with a Pearson correlation coefficient of -0.01. WS of 6, 7 and 13 m/sec was associated to the larger densities, but the Pearson correlation coefficient was only 0.16. The Best sub-sets multiple regressions did not improve much to these findings.

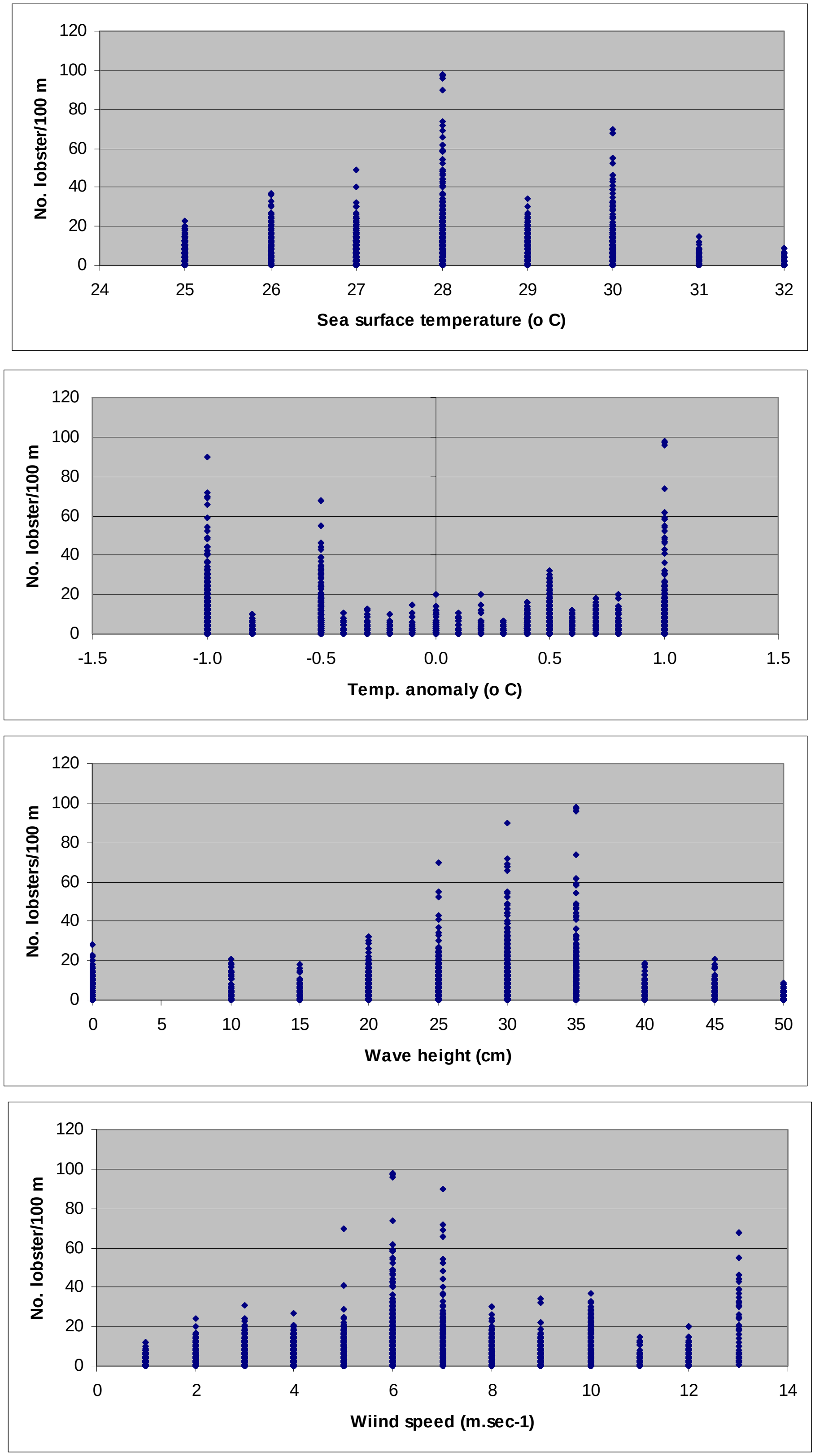

Figure 2. Plot of the San Andres Archipelago lobster densities against four environmental parameters.

Table 3. Comparison of maximum lobster densities (ind/25 traps) and its association to cold fronts or hurricanes.

Week number	Year	Date	Green Moon	Cluster	Queena	Event
28	2003	Jul 27	49			H. Claudette 1
29	2003	Aug 5	34	89.5	24.8	
30	2003	Aug 14	32.5	98.3	16.8	
31	2003	Aug 20	43	59	22	
35	2003	Sep 18		69		
52	2004	Jan 29		35.8		Cold front
53	2004	Feb 4		31.1		
75	2004	Jul 18			44	T. Bonnie?
133	2005	Oct 6	55			H. Wima 2
134	2005	Oct 13	68.3			
135	2005	Oct 21	29.8			H. Beta 1
136	2005	Oct 29	32.3			
137	2005	Nov 5	34			
173	2006	Jul 25	27.5			

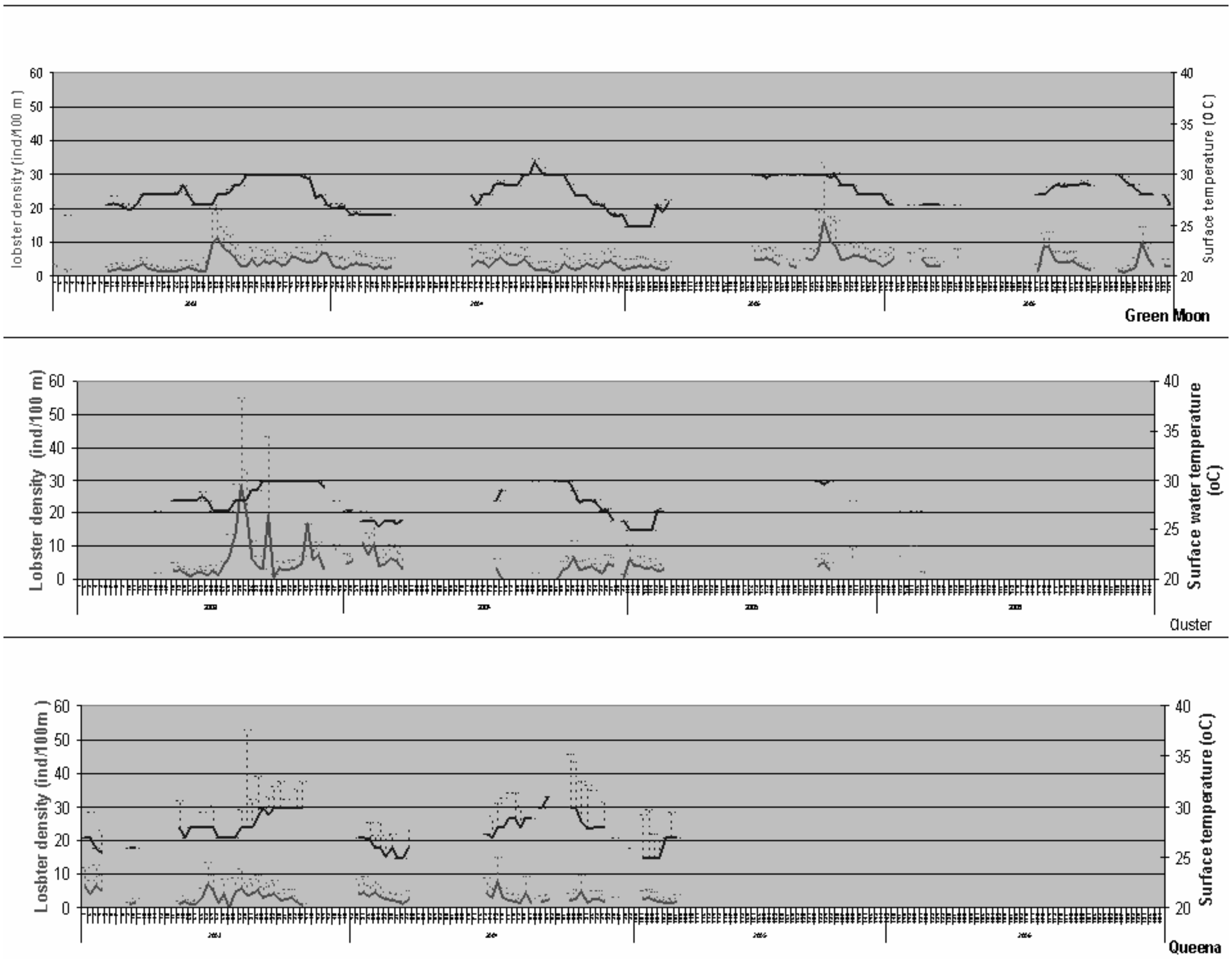

Figure 3. Example of weekly variation of lobster density and sea surface water temperature in three fishing zones of the San Andres archipelago.

DISCUSION

The lobster densities varied across the year and across the fishing zones, and there were not found a clear pattern when compared against the four environmental parameters analyzed. Special attention should be put into the Cluster areas as potential seamounts areas that congregate lobsters. However, detailed bathymetry information in these areas is needed to corroborate these findings.

Perhaps differences of the surface water data and the comparison of data at two different spatial scales influenced the presented results. Seawater temperature looks promised for further studies, but because values were not registered with the needed precision, more reliable relationships was not possible to be detected. The fact that only sparse information on water quality or benthic habitats for the study area is available, the detailed information gathered from the logs books could not be fully utilized.

The San Andres archipelago is the Colombia most northern frontier, and their insular shelves are comprised of well-developed coral reefs in relatively good healthy conditions (Diaz *et al.* 2000), with individual banks having its unique habitat characteristics and ecological interactions (Heinemman *et al*. 2003), thus having characteristics as good habitat grounds.

Higher peaks in lobster densities were associated with the effect of hurricanes and cold fronts. In fact, maximum lobster densities were found exactly two weeks prior to Wilma and Beta Hurricanes, and other important densities matched the first cold front. This knowledge has been long before in the traditional captain background, but this time were not possible to prove with the available scientific information. The effect of the lobster reproductive season matching the hurricane high season, still remain to be monitored, because it might indicate a progressive reduction in the resistance capacity of the lobster populations in the archipelago.

To fully understand the potential of the relationship between lobster densities and the environmental parameters, in situ measurements should be taken. Natural abundance of lobster in the archipelago can not be addressed only by looking at variations in the adult populations but in addition distribution of juveniles and recruitment phases need to be connected. Information of benthic habitats and other water quality parameter might be included.

Results presented here showed the importance of sharing information between fishers and managers towards a more appropriate fisheries management.

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