Forecasting Yield in a Spiny Lobster stock of the Northern Meso American Barrier reef System

ERNESTO A. CHÁVEZ AND KIM LEY-COOPER[1]
Centro Interdisciplinario de Ciencias Marinas, IPN. Av. Instituto Politécnico Nacional s/n,
Col. Sta Rita, Playa El Conchalito. La Paz, B.C.S., 23096 México
[1]*Instituto de Ciencias del Mar y Limnología-UNAM, México D.F.*

ABSTRACT

Monthly spiny lobster catch data of twenty two fishing seasons, from Chinchorro Bank Mexico were analyzed. The Bank holds an isolated stock, where recruitment to the fishery from other areas, or migrations in or out the Bank are considered non-significant. The fishery depletes the stock every nine-month fishing season and therefore it behaves as a depletion experiment and allowing the application of De Lury's method every year, finding that the stock size declined abruptly the first five years, it remained relatively steady for the next thirteen years, showing a tendency to recover the last four years of the series. Relative regularity shown by data allowed to try forecasting yield based on the previous months or years, this way second degree equations were applied to data and significant correlations were found; here, the catch of July and August were compared to total catch of the season as well as yield one year against yield the year before. Another parabola was also fitted to catch data arranged over time. Equations showed a reasonable good fit to data series, but with the exception of the only one, all others over estimate the expected value. By fitting catch data over time a very accurate and reliable procedure to forecast the spiny lobster catch for next year at Chinchorro Bank was found. Tendency of data suggests that if current conditions of the fishery and maintained, the stock might recover to the levels of 1988 when near 70 tons were caught and the catch value and the number of jobs could be three times higher than the current ones.

KEY WORDS: Stock assessment, forecasting yield, fisheries management, Chinchorro Bank, Meso American Barrier Reef System.

Pronóstico de la Captura de una Población de Langosta en Barrera Arrecifal Mesoamericano

Se analizaron datos de la captura mensual de 22 temporadas de pesca de Banco Chinchorro, México. El Banco alberga una población aislada donde el reclutamiento alóctono y las migraciones hacia adentro o afuera del Banco se consideran insignificantes. La pesquería agota la población en el curso de los nueve meses de cada temporada de pesca y por lo tanto se consideró apropiada para aplicarle el método de De Lury a cada año de datos, encontrándose que el recurso declinó abruptamente durante los cinco primeros años, permaneció relativamente estable durante las trece temporadas siguientes y mostró una cierta recuperación durante los cuatro últimos años de la serie. La relativa regularidad de los datos permitió intentar hacer pronósticos de la captura a partir de los datos de los meses o años previos de cada temporada de pesca y así ecuaciones de segundo grado fueron ajustadas, encontrándose correlaciones significativas; así, las capturas de julio y agosto, se compararon con la captura total de la misma temporada, se probó la correlación entre la captura de un año con respecto a la de la temporada anterior, así como también se ajustó una parábola a los datos de la captura dispuestos cronológicamente. Las ecuaciones mostraron un ajuste aceptable; sin embargo con la excepción de la última, todas las demás sobrestiman la captura. El simple ajuste de la curva a los datos históricos permitió hacer un pronóstico muy preciso de la captura del último año. La tendencia de los datos sugiere que la población tiende a aumentar debido probablemente a la reducción de un mes en la temporada de pesca y a los controles ejercidos desde el establecimiento de la Reserva de la Biosfera en 1996. Si se mantienen las condiciones actuales, se considera que se podría recuperar la población a los niveles que tenía en 1988 cuando se capturaron cerca de 70 t, con lo que se triplicarían los ingresos y el nivel de empleo.

PALABRAS CLAVES: Evaluación pesquera, pronóstico de captura, administración pesquera, Banco Chinchorro, Sistema Arrecifal Mesoamericano.

INTRODUCTION

The spiny lobster *Panulirus argus* fishery is one of the main economic activities in the Caribbean with more than 40,000 direct jobs and nearly 480,000 indirect jobs in the whole region. It is the most important exploited stock in the State of Quintana Roo, Mexico (Lozano-Alvarez et al. 1993, González-Cano 2000, González-Cano et al. 2000a, González-Cano et al. 2000b), where 256,974 tons were caugh in 2004, with 5 Million USD worth, approximately. At Chinchorro Bank (CB) this fishery represents almost 41% in value of all catch for the State and 72% of the fisheries exploited at this Biosphere Reserve, which has an area of 144,360 hec (Fig. 1); this Bank is a coral reef complex which has been considered as false atoll (Darwin, 1842), as an atoll (Jordán), and as a platform reef (Chávez et al., 1985). It provides jobs for 98 persons plus 15 others grouped in three fishermen unions. Previous reviews of this fishery at CB have been undertaken by Phillips B, Chaffee C (2000), and Sosa-Cordero (2003).

This study was conducted with the purpose of answering the following questions:

- What is the current situation of the spiny lobster stock in the Biosphere Reserve?
- If evidence is found confirming a situation of overfishing, then how can the stock be restored?
- Is there a simple approach to forecast the catch in the following fishing season and how reliable can be the approach?

By having in mind the above questions, a study with a wider scope than the results presented here was made, including a reconstruction of age structure, assessment of the stock and its socioeconomic implications; however, results presented here are limited to provide the basic answers the questions above mentioned based on an empirical approach as it is presented here.

The spiny Lobster Stock

There is marked trend in the catch over the fishing season. This pattern is interpreted as a stock response to its life cycle and when juveniles and young adults increase their size they move from the depth slope of the Bank to shallow areas (<15m) in response looking for new feeding grounds (Briones-Fourzan et al. 1997). This displacement to the shallow reef makes spiny lobster vulnerable to the fishermen, who exploit it using hook and only by free diving and therefore they constrain their fishing ground to the upper 15 m of the reef. With this consideration in mind, the stock subjected to fishing mortality is the only portion of it vulnerable to the fishery.

The Catch and The Fishery

All of the Caribbean captures of fish, spiny lobster, and conch have been declined since the sixties and the apparent cause is overfishing. This problem also occurred at CB for about ten years since the early eighties, when more than 67 tons of lobster tail were caught, then remained stable for another ten years around 20 tons and then the stock showed an apparent recovery since the last two years attaining almost 30 tons in the season 2004-05 (Fig. 2). Data examined in this paper include catch since 1982 when more than 67 tons were caught in the fishing season 2004-05.

Catch data of spiny lobster show a marked decline every year, starting at the beginning of the fishing season in July until the end of it in March. The mean of the fishing seasons (1982-2004) in July and August is above 6 tons and the mean at March is 2 tons.

In the first two years (1982 and 1983) more than 67 tons were caught with a sudden drop the year after with near 40 tons being maintained in this level for the next three years; from 1988 through 2002 the catch ranged around 20 tons. The stock shows an apparent recovery through the last two years, when the catch increased to 24 and 31 tons in 2004 and 2005 respectively. This increase may be a consequence of the establishment of the Biosphere Reserve in 1996, which imposed control on the illegal catch among other regulations (INE-SEMARNAP 2000); in addition, the fishermen took the decision of reducing the length of the fishing season in one month during the last five years, which means a significant reduction of fishing effort in approximately 33%.

METHODS

Catch data of the spiny lobster caught at CB were obtained from one of the fishermen unions (Langosteros del Caribe), whose catch represented 52% of total catch of the Bank. The tendency of catch over time suggests that the stock tends to depletion each year as consequence of the fishing intensity over the season and for this reason the possibility to apply the Delury's method was considered; this method is based on the principle that if a stock is depleted as consequence of exploitation, then an estimate of the catch can be made by doing a linear regression where one of the variables is accumulated catch and the other one contains partial catch values; this way, the intersection of accumulated catch with its axis provides an estimate of the expected catch at the end of the season. This procedure was applied to each one of the 23 fishing seasons as shown in Fig. 3 where the analysis for the chosen as example. Catch estimates for each of these years excepting the last one, were analyzed by fitting a second degree polynomial regression (the parabola); the last year was used to test the goodness of fit, with the intention to use it as potential target to forecast yield.

Another approach was applied by just using catch data and to describe their tendency another parabola was fitted.

Figure 1. Chinchorro Bank Biosphere Reserve

Here the last year was also used to test the goodness of fit, intending to use it as potential target to forecast yield. Four modalities of this procedure were applied; the first one consists in fitting the parabola by using the catch of July, the first month of the fishing season, as independent variable and the catch the year after was used a dependent variable; in the second part of the analysis the month of October was used instead of July and the dependent variable was the catch the following year. The third trial consisted in estimating catch the year after and using catch data the year before as independent variable. Finally, the last modality of analysis consisted in to fit the parabola to catch data over time. Catch data for the last year were left outside the regression analysis in all cases because were used as target to forecast. All the procedures applied were compared and the best one was chosen.

RESULTS

De Lury Approach

The marked seasonal trend in the catch as the fishing season proceeds is interpreted as real evidence of stock depletion and for this reason the application of the De

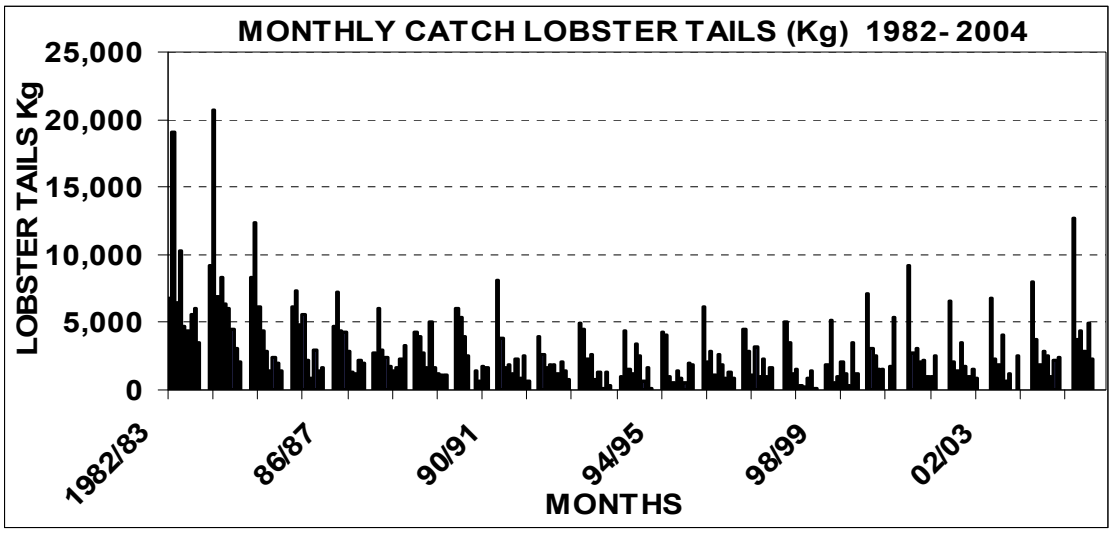

Figure 2. Monthly catch of spiny lobster tails at the Chinchorro bank Biosphere Reserve since 1982.

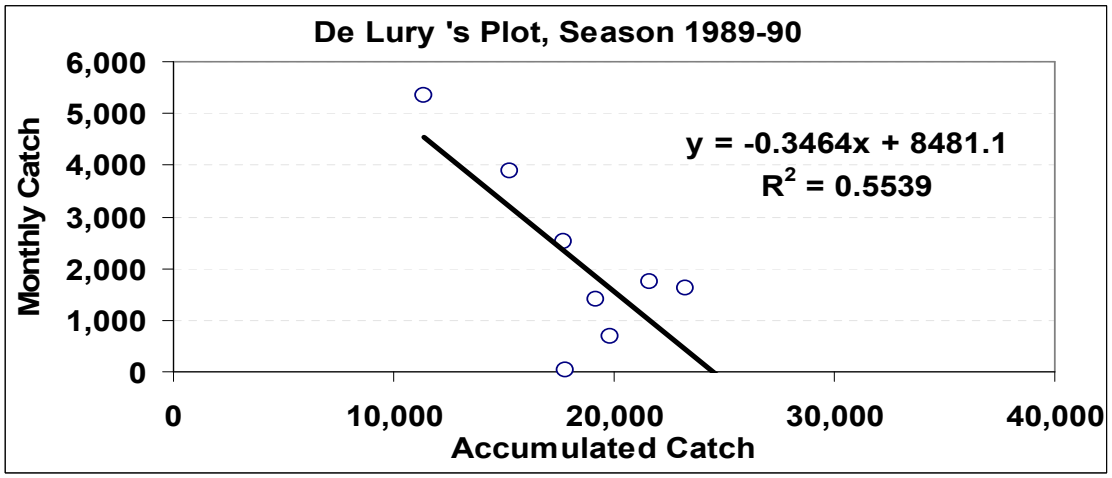

Figure 3. Application of the De Lury's method to estimate total catch during one year. Data for the 1989-90 fishing season are shown as example. The method was applied to each of the 23 fishing seasons of catch data for Banco Chinchorro analyzed.

Lury's method was considered a valid procedure, as shown in Figs. 3 and 4. At the initial stage of the analysis, when linear regressions were applied to each fishing season, in some years the goodness of fit had a high R^2, but not in others; the graph shown in Fig. 3 corresponds to the fishing season 1989-90, a year when the correlation was high.

Afterwards, to catch data obtained by this method a parabola was fitted using the years as independent variable; the line describing the parabola evidently shows a bias, the method by De Lury over estimates the catch and therefore the line fitted is biased (Fig. 4). In addition, standard error (s.e.) of this series of values is too high (s.e.= 41.6).

Empirical Data Fitting

The line fitted using the July data over estimates catch of the last year by about 15% respecting to the expected

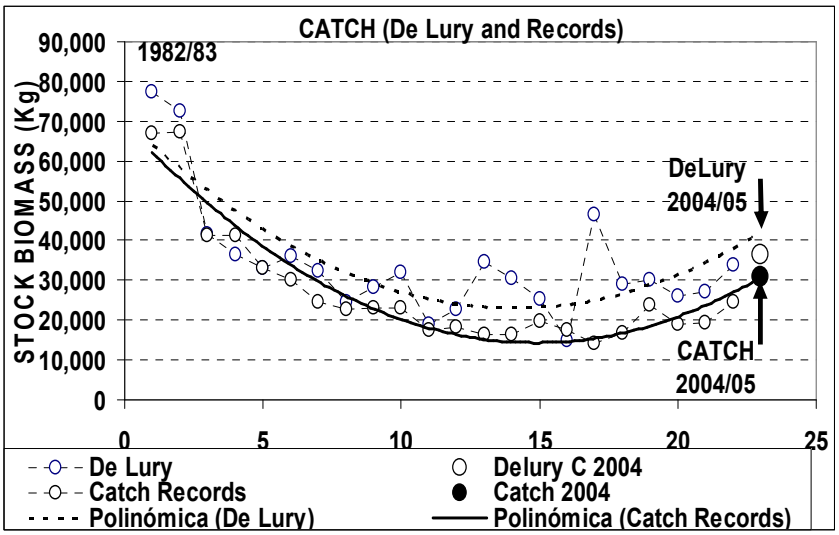

Figura. 4. Catch data records (line), estimates of catch after the application of De Lury's method (dotted line), and parabolas fitted to each series. The last point of each series corresponds to the target to forecast. Tendencies show that the De Lury's method over estimates the catch and therefore the line fitted is even more biased than empirical estimations using catch data directly, which provide a simple, convenient and reliable method to forecast yield one year in advance.

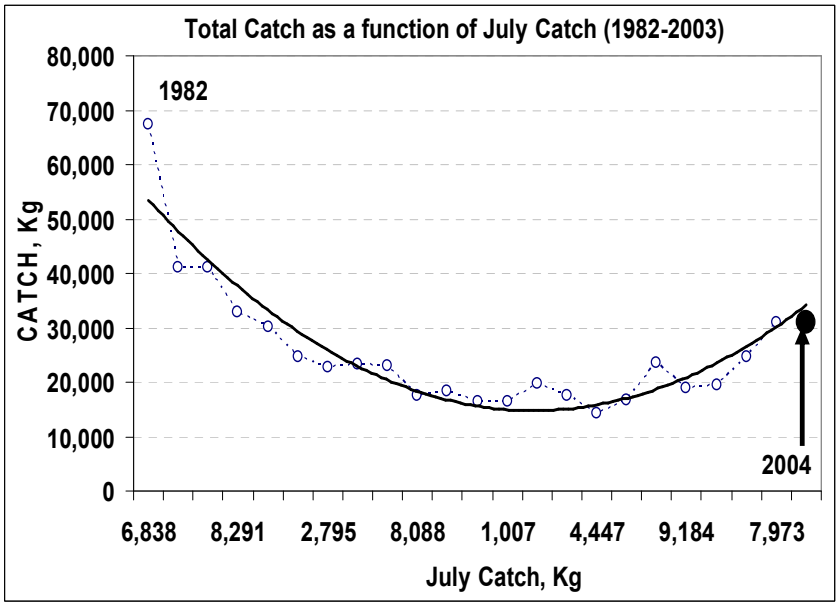

Figure. 5. Regression analysis fitting a parabola to catch data using July as independent variable and catch of the fishing season one year after as dependent variable. The last point of the series corresponds to the target to forecast. With this approach of analysis the result over estimates catch.

value; its s.e. = 42.6 (Fig. 5). When catch data for August were used, the results are identical those obtained in the former case (Fig. 6). The third attempt to get a reliable way to forecast yield was using one-year lag of total catch of the season as independent variable and the catch of the following year as dependent variable; results are no better than the former two (Fig. 7) and curve fitted also over estimates the expected yield in about the same proportion.

On examining the performance of the parabola fitted to catch data over time, it is observed a much better goodness of fit than in the former approaches (Fig. 4); here, the line fitted to data forecasts very well the catch of the last year used as target passing on the point of the last year, which as mentioned above, was not considered in the regression. For this reason, it provides a convenient and sim-

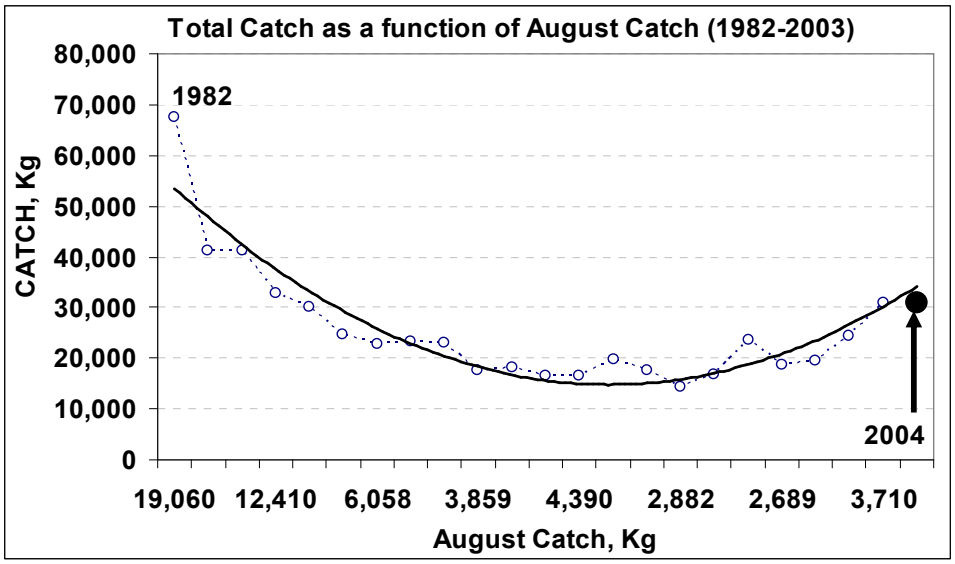

Figure 6. Regression analysis fitting a parabola to catch data using August as independent variable and catch of the fishing season one year after as dependent variable. The last point of the series corresponds to the target to forecast. With this approach of analysis the result over estimates catch.

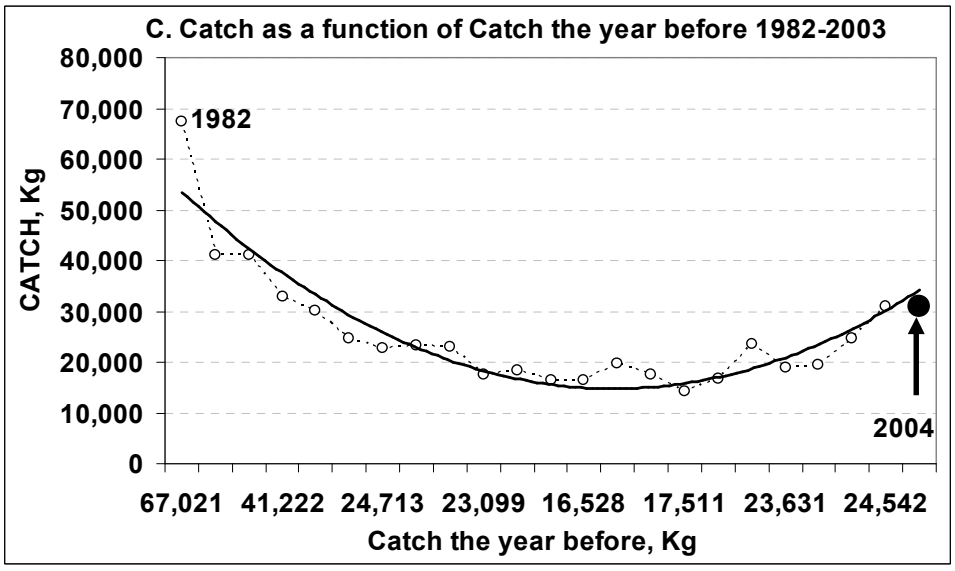

Figure 7. Regression analysis fitting a parabola to catch data using catch one year as independent variable and catch of the fishing season one year after as dependent variable. The last point of the series corresponds to the target to forecast. With this approach of analysis the result over estimates catch.

ple way to estimate the catch one year after and therefore a suitable tool for managing the spiny lobster stock of CB.

DISCUSSION

The existence of factors beyond those determining the current tendency may affect its performance and change the pathway. The most likely factors that may play an important role producing a significant change in the tendency of yield are changes in the policy of exploitation, like fishing intensity or age of first catch, a reduction in the intensity of surveillance avoiding poaching, global warming or an unexpected high recruitment. For this reason, the approach used here and its results should be taken with caution, especially when social and economical implications are considered.

On examining the size frequency of the catch, mean sizes prevail, whilst direct observations showed a higher abundance of larger animals in deeper, non exploited zones of the Bank. Therefore, deeper areas (>15 m), play a role as reserve of adult stock guaranteeing a permanent supply of recruits to the fishery, avoiding its exhaustion. Evidently this characteristic of the fishery implies some effects on the stock dynamics, probably affecting growth rate, vulnerability, reproductive potential, mortality and longevity.

In conclusion, a relatively simple and straightforward method to forecast the spiny lobster catch of CB for the following fishing season was found, by just using catch data and fitting a second degree equation over time. With the data used here, the method applied provided quite reliable results.

Although the information presented here does not show the evidence that the stock is still over exploited, detailed analysis of its dynamics not presented here, plus the empirical catch data analyzed in this paper allows us to sustain the idea that the spiny lobster stock of CB can recover to attain the yields obtained before 1986, near 70 tons. The catch obtained the last fishing season (2004) is a significant increase providing confidence in the idea that the population is growing and the main reason to explain it is the significant reduction of fishing effort since 1996 in nearly 30% per year.

Regulations for the exploitation of the spiny lobster in Mexico have been applied since 1967 (Lozano-Alvarez 1994); however, each fishing stock deserves particular considerations and regulations to optimize the benefits of the fishery and the conservation of the stock. In the case of CB, it is hoped that the fishing authorities as well as those of the Biosphere Reserve, can take care of the fishery enforcing the maintenance of its current conditions, this is, the same levels of fishing effort (98 fishers in an eight-month fishing season), the current minimum legal size (135mm of tail length), no take of egg-bearing females, fishing only by free-diving and strictly controlling illegal catch. If these conditions are met, then there is strong confidence feeling that the stock may recover to the levels it had in 1982-83; when this occur, significant increase of income will benefit the fishermen exploiting the spiny lobster at the Bank and the number jobs will be at least twice the current number.

AKNOWLEDGEMENTS

E. Chávez holds a fellowship from COFAA-IPN.

LITERATURE CITED

Briones-Fourzan P, E. Lozano-Alvarez, M.A. Cabrera. 1997. Biología y Ecología de las langostas (Crustacea: Decapoda: Palinuridae). Análisis y Diagnóstico de los Recursos Pesqueros críticos del Golfo de México. *EPOMEX Serie Científica* **7**:81-99.

Chávez, E. A., E. Hidalgo y M. A. Izaguirre. 1985. A comparative analysis of Yucatan coral reefs. Vol. 6: 355-361. Fifth Internacional Coral Reef Congress, Tahiti.

Darwin, C. 1842. The structure and distribution of coral reefs. London: Smith, Elder and Co.

González-Cano, J., Porras, R.R., and C.C. Aguilar. 2000a. Componente langosta. *In*: Análisis de tres pesquerías en la Reserva de la Biosfera Banco Chinchorro, Quintana Roo, México. Amigos de Sian Ka ´an, INP y WWF, Reporte Final. 61 p: 6-18

González-Cano, J, V. Ríos-Lara, A. Ramírez-Estévez, C, Zetina-Moguel, K. Aguilar-Cardozo, H. Cervera-Cervera, J. Martínez, R. Mena-Aguilar, and M. T. Cobá-Ríos. 2000b. La pesquería de langosta en el Caribe. *In*: Sustentabilidad y Pesca Responsable en México. Evaluación y Manejo. Instituto Nacional de la Pesca. SEMARNAP. México.

INE-SEMARNAP. 2000. Programa de Manejo de la Reserva de la Biosfera de Banco Chinchorro. Instituto Nacional de Ecología. México D.F. 60 pp.

Jordán, E, and E. Martín. 1987. Chinchorro: morphology and composition of a Caribbean atoll. *Atoll Res. Bull.* **(310)**:1-25.

Lozano-Alvarez, E. 1994. Análisis del Estado de la Pesquería de la Langosta *Panulirus argus* en el Caribe Mexicano. pp: 43-55. *In*: Yáñez-Arancibia (ed). Recursos Faunísticos del Litoral de la Península de Yucatán. Serie Científica 2. EPOMEX Universidad Autónoma de Campeche.

Lozano-Alvarez, E., P. Briones-Fourzan, F. Negrete-Soto. 1993. Occurrence and Seasonal Variations of Spiny Lobsters, *Panulirus argus,* (Latreille) on the shelf outside Bahía de la Ascención, México. *Fishery Bulletin US* **91**:808-815.

González-Cano, J., F. Márquez-Farias F., and A. Ramírez. 2001. Evaluación Preeliminar de la fracción de la población de langosta que se captura en aguas someras de Banco Chinchorro, Q. Roo. Instituto Nacional de Pesca, CRIP Pto. Morelos, México.

Sosa-Cordero, E. 2003. Trends and Dynamics of the Spiny Lobster, *Panulirus argus,* resource in Banco Chinchorro, México. *Bull. Mar. Sci.* **73 (1)**:203-217.