A review of the methodologies used for monitoring and evaluation of the spiny lobster stocks in the WECAFC countries and the development of a common methodology

A review of the methodologies used for monitoring and evaluation of the spiny lobster stocks in the WECAFC countries and the development of a common methodology

Prepared by: Maren Headley[1,2] and Juan Carlos Seijo[2]

[1] CRFM Secretariat, P. O. Box 642, Princess Margaret Drive, Belize City, Belize. Email: marendheadley@gmail.com
[2] Universidad Marista de Mérida, Periférico Norte Tablaje 13941, Carretera Mérida-Progreso, Mérida, 97300, Yucatán, México. Email: jseijo@marista.edu.mx

ACKNOWLEDGEMENTS

The CRFM provided technical leadership for the study, which was financed by FAO/ WECAFC. This report is the result of a collaborative effort among the experts and scientists of various institutions and organizations throughout the WECACFC area who share a common interest in the management of the spiny lobster resource and fisheries.

We acknowledge the efforts of the following national survey respondents listed in alphabetical order: Jean Robert Badio; Erik Bowman; Michael T. Braynen; Paulo Parente Lira Cavalcante; Christine Chan A Shing; Manoel Cifuentes; Luc Clerveaux; Rafael Tizol Correa; Lester Gittens; Mauro Gongora; Martin de Graaf; Vladimir Puentes Granada; James C. Gumbs; Olivier Guyader; Samuel Heyliger; Ian Horsford; Crafton Isaac; Kris Isaacs; John Jeffers; José Guadalupe Trujillo Jiménez; Jeannette Mateo; Tom Matthews; Patricia Hubert-Medar; Juan Luis Córdoba Mora; Ricardo Morris; Thomas Nelson; Anna Núñez Pereligina; Dulce Nathalie Arocha Pérez; Aldo Gerardo Padilla Pestaño; Joanna Pitt; Lionel Reynal; Danilo Pichardo Rosales; Miguel Suazo; Raúl Adán Romo Trujillo.

We are also grateful to Mario Gonzalez and Manuel Perez of OSPESCA for their provision of the translated Spanish version of the questionnaire and assistance with contacting the SICA Member States.

The authors thank the following reviewers for their comments and suggestions which greatly improved the report: Elizabeth Mohammed and Susan Singh-Renton of the CRFM Secretariat, and John Jorgensen and Tarub Bahri of FAO.

CONTENTS

PART I: A REVIEW OF THE SURVEY AND STOCK ASSESSMENT METHODOLOGIES FOR CARIBBEAN SPINY LOBSTER APPLIED IN THE WECAFC REGION

1. EXECUTIVE SUMMARY

This report provides "A review of the methodologies used for monitoring and evaluation of the Spiny Lobster (*Panulirus argus*) stocks in the Western Central Atlantic Fishery Commission (WECAFC) countries and the development of common methodology."

A questionnaire was circulated to a total of 33 WECAFC Member States. Responses were received from 30 countries. These countries included: Anguilla, Antigua & Barbuda, The Bahamas, Belize, Bermuda, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Caribbean Netherlands-Saba and St. Eustatius, Nicaragua, Panama, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, Turks and Caicos Islands, United States of America, and Venezuela.

For the spiny lobster fishery, countries provided information on the number of fishers and vessels active during 2012; the average landings during 2002-2012; and the types of vessels, gears and methods used. The types of data available, and the survey methods used to collect catch and effort data were reviewed. Information was also provided on the methods used to assess the status of the spiny lobster stocks. Each assessment method was described and characterised according to its suitability for application to the spiny lobster fishery in the WECAFC area based on the available data. It was found that length frequency data were the most frequently available biological data and the most commonly used assessment method was length cohort analysis. Based on these findings, the adoption of length cohort analysis and eventually virtual population analysis as common assessment methodologies was proposed. It was recognised that a country specific approach is required for the implementation of length frequency data collection programmes and the application of length cohort analysis/virtual population analysis methods, however, a general approach was outlined. As an interim analysis method, the application of catch models was suggested for those countries which do not currently have length frequency data. The importance of involving the private sector in the data collection process was recognised and the types of data which could be collected on a collaborative basis were identified. The main recommendations of the study were related to fishery-dependent information, fishery-independent information, involvement of the private sector in data collection, development of assessment methods, implementation of regional assessment methods, and investigation of regional spiny lobster status. Steps which can be taken at the local level to improve regional management of the spiny lobster resource were also outlined.

2. INTRODUCTION

The Caribbean spiny lobster (*Panulirus argus*) is distributed throughout the Western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico from Bermuda down to Brazil (Herrnkind, 1980). The spiny lobster inhabits shallow waters and can occur in depths down to 90 m. Throughout its geographic range, the spiny lobster supports commercial, recreational and artisanal fisheries. The landings of spiny lobster peaked at approximately 43 thousand tonnes in 1997 (Figure 1), with an estimated value of 300 million US dollars. However after this peak, significant declines in landings occurred with approximately 27 thousand tonnes being landed in 2010. (Figure 1)

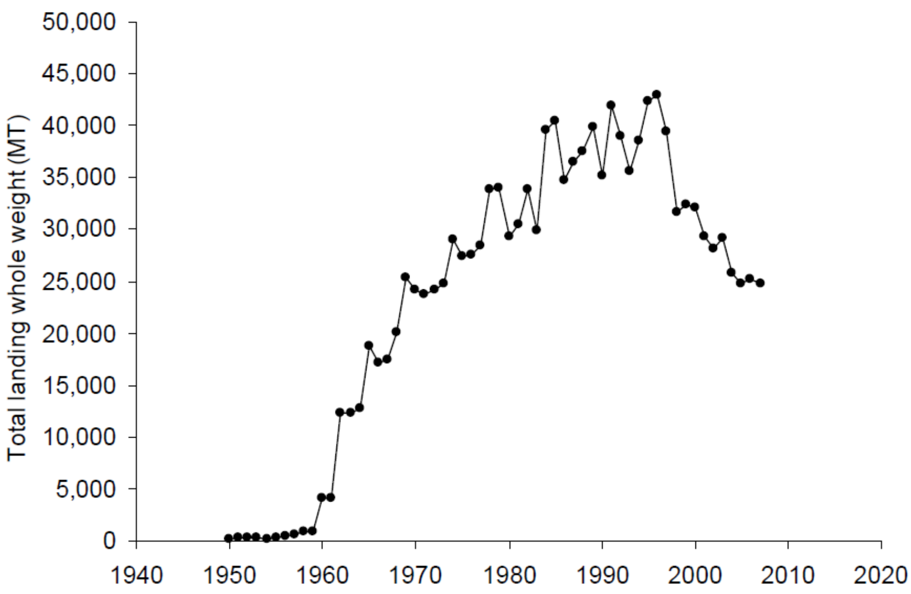

Figure 1: Total Caribbean wide (including Brazil) landings of spiny lobster, Ehrhardt, 2010.

The spiny lobster (*Panulirus argus)*is considered as a pan-Caribbean metapopulation which includes a set of local populations connected by a large number of individuals migrating in different stages of the life cycle: larvae drifting northward in the Caribbean basin and Gulf of México, and adults migrating in deeper reef waters crossing geopolitical boundaries. The maximum potential dispersal distances differ from one region to another and are primarily dependent on the currents and gyres in the area and large-scale sporadic events such as hurricanes.

This connectivity imposes management difficulties because not all of the countries in the WECAFC area implement the same stock assessment approaches or use the same regulatory strategies for this resource.[3]

[3] The Brazil population of spiny lobster is considered to be genetically distinct from the Caribbean populations.

The following set of complexities have been identified for the management and conservation of the spiny lobster fisheries and resource in the Western Central Atlantic area: (i) the transboundary nature of the resource, (ii) it is characterized by a metapopulation with source-sink configuration[4], (iii) the use of heterogeneous gears and fishing methods with differing effects on population structure, and (iv) the heterogeneity in management strategies, regulations (including differing legal sizes and trade restrictions), and enforcement (Cochrane *et al*., 2001; Cochrane and Chakalall 2007, Seijo 2007). Successful management and conservation of the spiny lobster is therefore dependent on: cooperation in joint research and assessment; good conservation practices and stewardship of the resource and habitat by fishers and coastal communities and an understanding of its life cycle and the transboundary behaviour in its different stages, and responsible regional fishery co-management.

2.1 Life cycle and transboundary nature of Spiny Lobster *Panulirus argus*

The complex life history of spiny lobster includes five stages with distinctive behavior and habitat requirement: (i) adults; (ii) egg; (iii) larvae (phyllosoma); (iv) postlarval (puerulus) and (v) juveniles (Lipcius and Eggleston, 2000) (Figure 2). Reproduction occurs through external fertilization in deep water where the females also release egg masses, which have a gestation period of one month. After hatching, phyllosoma larvae drift with the currents for a period of 6 to 11 months during which they undergo eleven stages of metamorphosis. Spiny lobster larvae (phyllosoma I), are released in the water column where they are at the mercy of currents as part of the zooplankton, and during this period they undergo metamorphosis through 11 larval stages (Lewis *et al*. 1952; Baisre and Cruz, 1994). When larvae reach the last stage (phyllosoma XI), they become pueruli with a total length of approximately 2 cm. The pueruli migrate towards the coast settling in the benthos characterized by the presence of sea grasses (Marx and Herrnkind, 1985) and mangrove roots[5]. After continuous molting, *P. argus* reaches a post-pueruli stage with an approximate size of 6-15mm carapace length (CL), at 10-15 months after settlement (Butler *et al*, 1997; Cruz *et al*., 1995). The post-pueruli continue growing in mangrove areas until they become small juveniles of 26-35mm CL, with an estimated age of 2 years after settlement. Late juveniles (>35 mm CL) and sub-adults tend to occupy patches of reef habitats without vegetation (Arce *et al*., 1997). As a sub-adult, the spiny lobster begins its migration to deeper reef areas where it continues growing until reaching the size of first sexual maturity (78-83mm CL). In this last process, adults can cross geographical boundaries from one Exclusive Economic Zone (EEZ) to another within the Western

[4]In source habitats, self-recruitment is considerable, whereas in sink habitats populations depend to a greater extent on reproductive surpluses from source habitats (Pulliam 1988).
[5]In this last stage, coastal fishing communities should take responsibility to protect critical habitats (i.e. sea grass and mangroves) of pueruli, juveniles and young adults.

Central Atlantic area. The long larval dispersal period also means that spawning spiny lobster stocks located southward in the Caribbean basin are a source of post larvae for countries located northward.

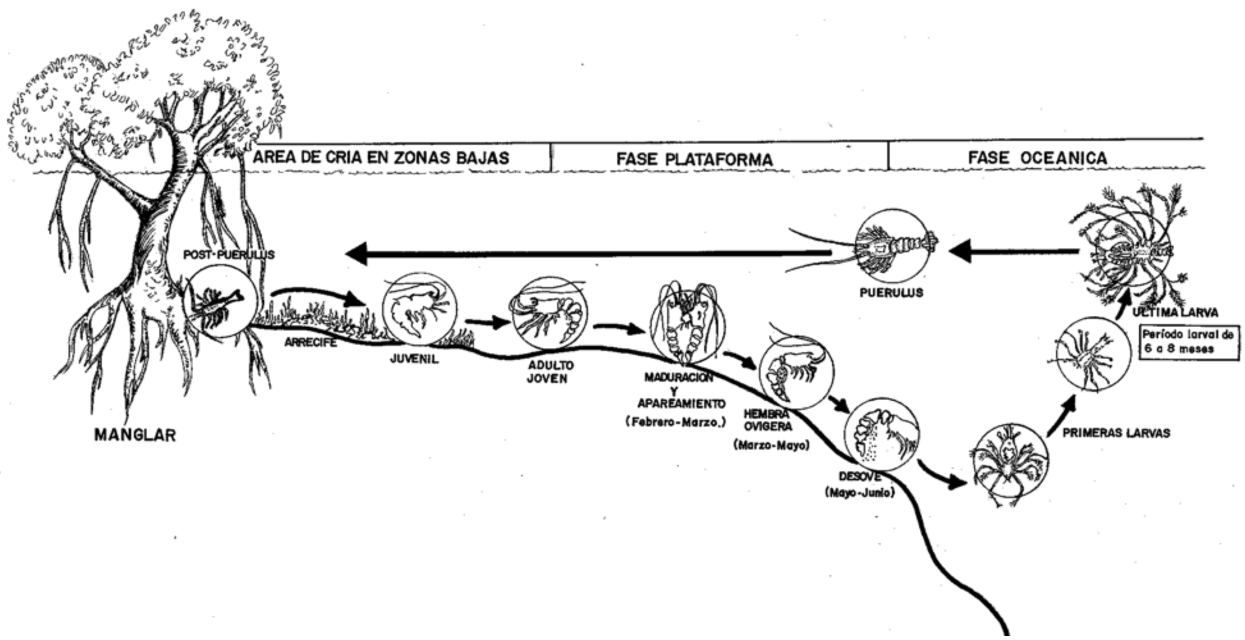

Figure 2: The life-cycle and associated habitats of the spiny lobster (Cruz, 1992).

2.2 Cooperation for Assessing Spiny Lobster Fishery in the WECAFC Area

There has been regional co-operation in assessing the status and management of the spiny lobster under the auspices of FAO WECAFC. Workshops were hosted in Belize City, Belize, 1997; in Merida, Mexico, 1998 and 2000; Havana, Cuba 2002; and in Merida, Mexico 2006.In the last spiny lobster working group meeting the main recommendations related to monitoring and evaluation of stocks are summarized as follows (FAO, 2007):

i) The workshop noted that technical support was required in many countries for determining, amongst others, what data should be collected in order to monitor and assess the effectiveness of different management policies and regulations (e.g closed seasons, closed areas, minimum size, fishing effort and total allowable catches). It was recommended that countries which require technical support should request it from the various agencies currently working in fisheries management in the region.

ii) The high incidence of capture of juveniles in the fishery needs to be addressed as a high proportion of sub-adults in the total catch can only be sustained at low fishing mortality rates. Therefore, when determining the maximum allowable fishing effort, countries will need to take into account the catch of juveniles. If countries are effective in reducing catch of juveniles, the sustainable yield will be higher than it would be if those catches cannot be controlled. The allowable fishing effort should ensure that the spawning stock is not reduced to low levels at which future recruitment could be reduced. Good data and scientific advice will be required to determine these trade-offs and the maximum allowable effort in each case.

iii) It was recommended that countries which currently have effective monitoring programmes in place should consider the implementation of programmes for the construction of recruitment indices. This would provide an index of recruitment at the regional level. Recruitment indices are not only useful for stock assessment, but they will support research on the spatial distribution of larvae and recruitment. This will aid the management of this shared resource in the medium to long-term.

The Caribbean Regional Fisheries Mechanism Conch and Lobster Resource Working Group (CRFM CLWG) has been meeting annually since 2004. The CLWG has completed assessments of the spiny lobster resource in The Bahamas (CRFM, 2005; CRFM, 2006; CRFM, 2007; CRFM, 2008; CRFM, 2009; CRFM, 2011).

In addition to regional working group activities, The Belize Declaration on CRFM-OSPESCA cooperation for Sustainable Development of Fisheries and Aquaculture Resources[6], agrees to "develop and implement a joint Action Plan for the responsible management of migratory fish stocks of the Caribbean Sea that consider among others, the progressive incorporation of CRFM countries into the regulatory framework for the lobster fishery in the SICA countries."

2.3 Objectives

Recognizing that the spiny lobster fishery constitutes one of the most important fisheries in terms of income and employment in the region of the WECAFC, and concerned about the decreasing catches and declining stocks in some areas, the 14th Session of WECAFC decided to re-establish the Working Group on spiny lobster under the leadership of the Organización del Sector Pesquero y Acuícola del Istmo Centroamericano (OSPESCA), Caribbean Regional Fisheries Mechanism (CRFM) and WECAFC. Among the tasks identified for the Working Group were:

"Develop common methods to assess and monitor spiny lobster stocks. Involve the private sector in data collection." In order to guide the activities of the Working Group, The Food and Agriculture Organization of the United Nations solicited the services of the CRFM Secretariat, to provide "A review of the methodologies used for monitoring and evaluation of the spiny lobster stocks in the WECAFC countries and the development of common methodology."

In fulfilment of the objectives, the following items were completed:

[6] Output of a high-level meeting among Ministers of Fisheries and Aquaculture Resources in CRFM and OSPESCA countries held in Belize, September 2012.

i) A report on the results of a survey on monitoring systems and stock assessment methodologies for Caribbean spiny lobster applied by the member countries of the WECAFC.

ii) A proposal for an appropriate, common and scientifically robust survey and stock assessment methodology for Caribbean Spiny lobster for application in the WECAFC area, which, to the extent possible, involves the private sector.

3. METHODS

The approach undertaken to achieve the above mentioned objectives involved the following steps:

a.) A questionnaire (Appendix 1[7]) was designed and circulated to a total of 33 WECAFC Member States. These included: Anguilla, Antigua & Barbuda, The Bahamas, Barbados, Belize, Brazil, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, France, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Montserrat, Mexico, Caribbean Netherlands, Nicaragua, Panama, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Suriname, Trinidad & Tobago, Turks and Caicos Islands, United Kingdom, United States of America, and Venezuela.

b.) The questionnaire solicited information on the number of fishers and vessels active during 2012 and the gears and methods used in the spiny lobster fishery. It was also aimed at obtaining average landings and exports during the ten year period from 2002-2012. The types of data available, and the survey methods used to collect catch and effort data and the assessment methods each country uses to manage their fisheries were also requested in this instrument.

c.) Questionnaire survey data were tabulated and summarized by country for analysis purposes.

d.) For each type of assessment method used in the WECAFC area; a description, data requirements, analytical capacity requirements, software, outputs, advantages, and limitations were provided.

e.) For each type of assessment method; the suitability for the spiny lobster fishery in the WECAFC area, the suitability for countries collecting length frequency data, and countries with current applications were also identified.

f.) A set of recommendations was developed to facilitate the establishment of a common stock assessment method for the spiny lobster fisheries of the WECAFC area.

4. RESULTS

The list of persons who completed the questionnaires and their designations is provided by country in Appendix 2. The tabulated summaries of responses received from 30 countries are available as Appendix 3. These countries included Anguilla, Antigua & Barbuda, The Bahamas, Belize, Bermuda, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Grenada, Guadeloupe, Guatemala, Haiti, Honduras,

[7] The Spanish speaking countries received the questionnaire in Spanish - OSPESCA kindly made the translation.

Jamaica, Martinique, Mexico, Montserrat, Caribbean Netherlands-Saba and St. Eustatius, Nicaragua, Panama, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, Turks and Caicos Islands, United States of America, and Venezuela. Table 1 provides a summary of the number of fishers, boat categories and size ranges which were active in the spiny lobster fishery during 2012. Table 2, provides the average landings and exports of spiny lobster in whole weight during the ten year period from 2002-2012 by country. In cases where the landings and export data did not represent the full ten year period, or whole weight, the years and measurement type were indicated. Table 3, lists the gears and methods used to harvest the spiny lobster. Table 4, provides a summary of the categories used by countries to classify their spiny lobster fishery. Table 5, provides a summary of the methods used to collect catch data, while Table 6 provides a summary of the methods used to collect effort data. Table 7, provides a summary of the sampling units used to estimate total catch, while Table 8 provides a summary of the methods and units used to calculate total effort. Tables 9, 10 and 11 provide summaries of the types of biological, ecological and economic data available for the spiny lobster fishery. Tables 12-a and 12-b provide summaries of the types of assessment methods which have been applied by the countries.

A list of references regarding data, assessments and the spiny lobster fishery by country is included in Appendix 4.

4.1 Landings and export data

In Table 1, the landings and export data provided by countries are presented. The data are arranged by the highest landed value to the lowest landed value. In cases where the data do not represent the full ten year period from 2002-2012, the years are indicated. Although, there are variations in the time and area represented, the productivity trends can be observed by country.

Table 1: Landings and export data for spiny lobster by country.

Country	Average landings (t) (2002-2012)	Average export (t) (2002-2012)
Brazil	6960 (2002-2011)	2174
Cuba	4800	
Nicaragua	3954	3186
Bahamas	2948	2507
United States-Florida	2000	
Colombia-San Andres and Providencia	1560	
Dominican Republic	1331	39 (2007-2011)
Mexico	1060 (2001-2011)	60% (2012)
Honduras[8]	816.47	6517.68
Belize	693	654
Turks& Caicos Islands	319	91

[8] The discrepancy in export data being significantly higher than landings data has been attributed to inaccurate data recording and reporting (Box, 2013)

Antigua and Barbuda	239 (2002-2010)	47 (2002-2010)
Anguilla	101.3	<10
Saba	100	100
Guadeloupe	98 (2011)	
Venezuela	58	
Martinique	49.6 (2011)	
Colombia (la Guajira)	45.4	
Bermuda	37.2	
Costa Rica	31.7	
Grenada	25.6	3.8
St. Vincent& The Grenadines	21	17
St. Kitts & Nevis	17	
St. Lucia	15.9	
Guatemala	1.7 (2012)	
Trinidad & Tobago	1.7 (2006-2010)	
Haiti		320
Jamaica		283

4.2 Number of fishers and boat categories

The number of active lobster fishers within the countries ranged from 9 to 11,000 in 2012[9]. The small-scale boat category was identified by 24 countries (Figure 3), with numbers of boats ranging from 8 to 3704. The semi-industrial boat category was identified by seven countries, with the numbers of boats ranging from 2 to 350. The mothership boat category was identified by two countries, with the number of boats being 3 and 22. The industrial boat category was identified by three countries, with the numbers of boats being 32, 65 and 122. For each of the four boat categories, countries were also asked to provide the associated size ranges. It was found that there was a wide variation in the size ranges provided for each boat category. Therefore no common size range could be assigned to each boat category. It is recognized that the number of boats as well as boat category is influenced by the scale of the fishing operations in each country.

[9] Appendix 3-Table 1

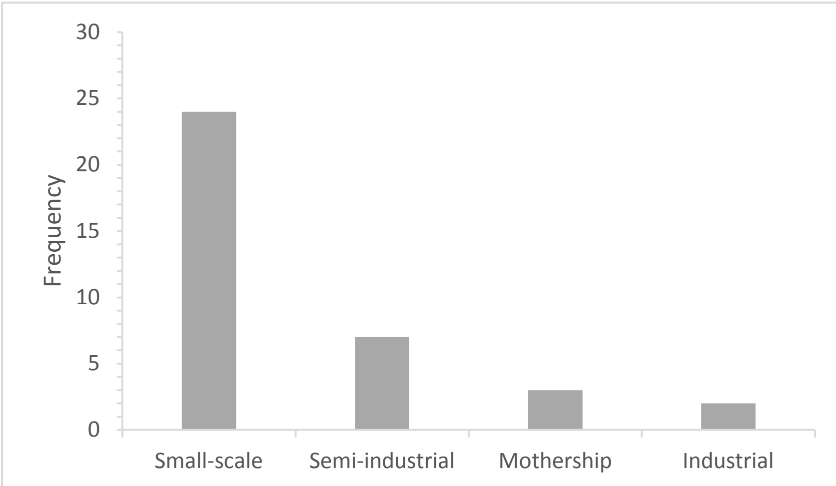

Figure 3: Frequency of boat categories used in the spiny lobster fishery identified by the 30 countries.

4.3 Fishing Gear and Methods

Traps were the most frequently used fishing gear with 28 countries indicating their use. Free diving was the second most frequently used method identified by 26 countries. The other two diving categories were SCUBA and compressed air/Hookah and their use was indicated by 12 and 10 countries respectively. The use of lobster aggregating devices was indicated by 12 countries. The use of gill nets and trammel nets was identified by 7 and 6 countries respectively (Figure 4). These gears and methods vary in design, size, deployment and use by country and therefore have implications for the estimations of parameters such as selectivity and catchability and the implementation of a common assessment methodology.

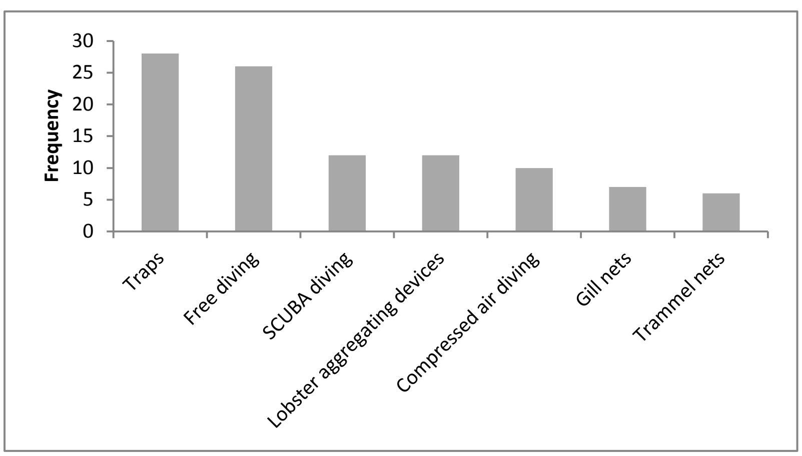

Figure 4: Frequency of fishing gears and methods used in the spiny lobster fishery identified by the 30 countries.

4.4 Survey standards for the collection of catch and effort data

Catch and effort data are usually collected based on survey standards which are country and fishery specific and dependent on the financial and human capacity available for data collection. Survey standards combine the stratification of domains to be sampled (e.g provinces of a country, months of the year, landing site), and classification of units to be measured (e.g. boat or gear category, species, weights). In the case of catch data, the survey standards most frequently identified were a given reference period (22 countries), a geographical area/stratum (21 countries), and a specific boat/gear category (12 countries). Twelve countries indicated the use of specific boat/gear categories as a classification system for sampling of catch data (Figure 5).

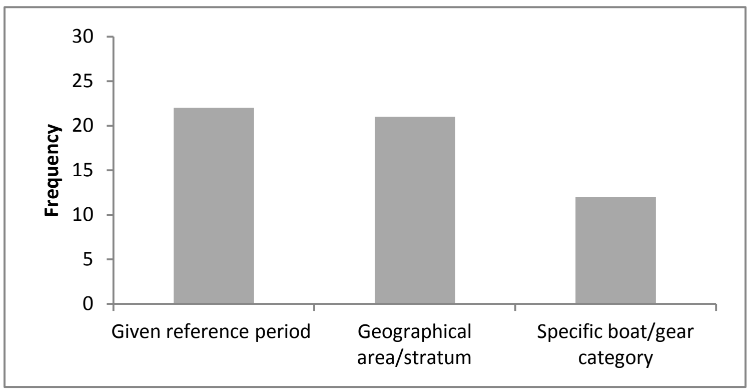

Figure 5: Frequency of survey standards used for the collection of catch and effort data in the spiny lobster fishery identified by the 30 countries.

The criteria used for defining boat/gear types are usually based on known or assumed differences among fishing gear/method, boat size, fishing trip patterns, spiny lobster size and catch rates. Definition of these criteria is done to ensure that total estimations based on sampled data are accurate. Fishing gear/method and boat size were the most common criteria used to define the boat/gear types and were indicated by 21 and 14 countries respectively (Figure 6). Fishing trip patterns (6), spiny lobster size (4) and catch rates (1) were not as common.

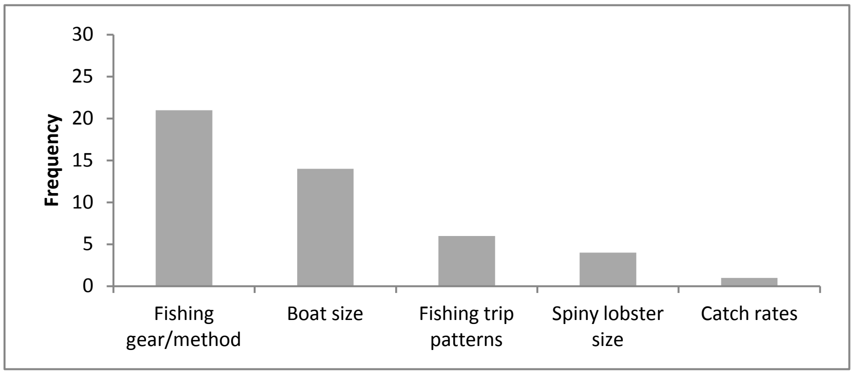

Figure 6: Frequency of criteria used in the definition of boat/gear categories used in the spiny lobster fishery identified by the 30 countries.

In the case of effort data, the most frequently used sampling method was temporal sampling, and spatial sampling (13 countries). This approach is the most economical as effort data are only collected from a few sites on selected days (given reference period). However this approach also has the most assumptions regarding the estimation parameters. The use of a spatial census and temporal sampling was identified by 6 countries. The use of a temporal census and spatial sampling was identified by 4 countries. The use of a complete census to calculate total effort was identified by 7 countries (Figure 7).

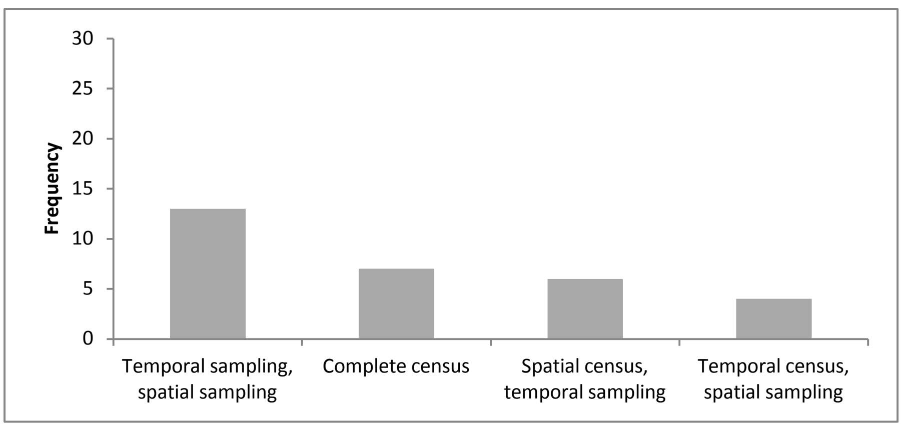

Figure 7: Frequency of approaches used for the estimation/calculation of effort data identified by the 30 countries.

4.5 Methods used to monitor and record spiny lobster catch and effort data

Countries were asked to indicate the methods used to monitor and record spiny lobster catch and effort data based on the following four categories: (i) data collectors[10]; (ii) market records; (iii) export records;

[10] Monitor and record catch and effort data through interviews or direct observation at landing sites, processing plants or markets.

(iv) observer programmes[11]; and (v) logbooks. Data collectors were used most frequently to collect catch data (25 countries) and effort data (21 countries). The use of export records for the collection of catch and effort data was identified by 13 and 11 countries respectively. The use of logbooks for the collection of catch and effort data was identified by 13 and 4 countries respectively. The use of market records for the collection of catch and effort data was identified by 9 and 2 countries respectively. The use of observer programmes for the collection of catch and effort data was identified by five and two countries respectively. For each method of data collection, it can be seen that catch data was more frequently collected than effort data (Figure 8).

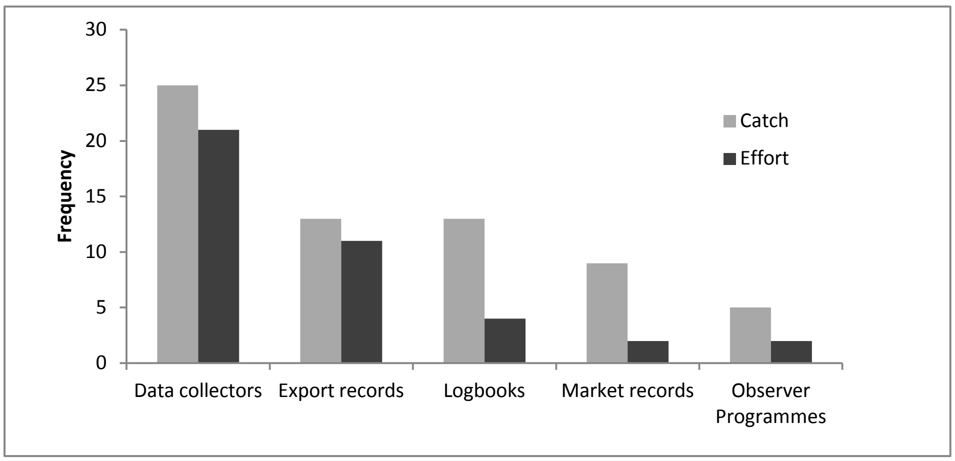

Figure 8: Frequency of methods used to monitor and record catch and effort data in the spiny lobster fishery identified by the 30 countries.

4.6 Data Availability

In the case of biological data availability, the most frequently identified types were sex (21 countries) and carapace length (20 countries). The availability of whole weight was identified by 13 countries, whereas the availability of tail weight was only identified by 7 countries. The availability of total length data and age data were identified by 6 and 5 countries respectively (Figure 9).

[11] Monitor or record catch and effort data through direct observations at sea, landing sites, processing plants or markets.

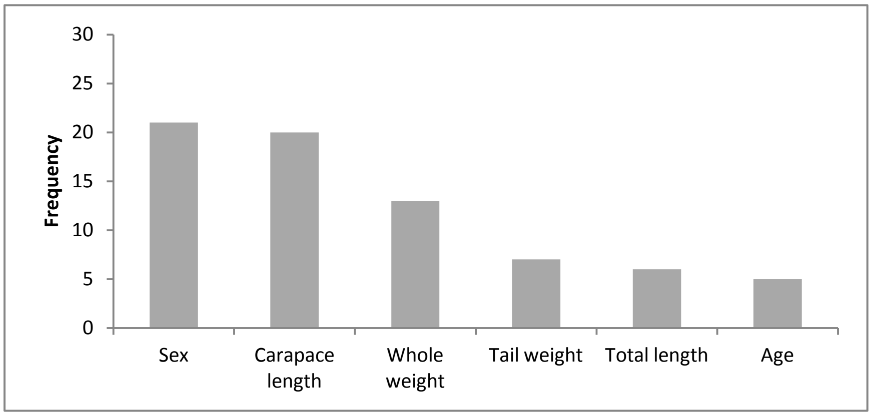

Figure 9: Availability of spiny lobster biological data identified by the 30 countries.

Ecological data were not readily available. Nine countries indicated the availability of habitat information and two countries indicated the availability of species interactions (Figure 10).

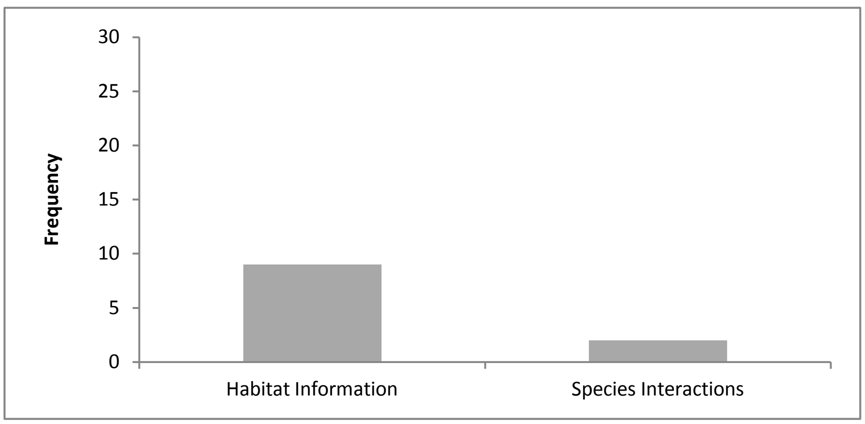

Figure 10: Availability of ecological data for the spiny lobster fishery identified by the 30 countries.

Overall, less than half of the countries indicated the availability of economic data. Eleven countries indicated the availability of size specific ex-vessel prices. Ten countries indicated the availability of investment costs, and operational costs by boat/gear category. Nine countries indicated the availability of profits by boat/gear category (Figure 11).

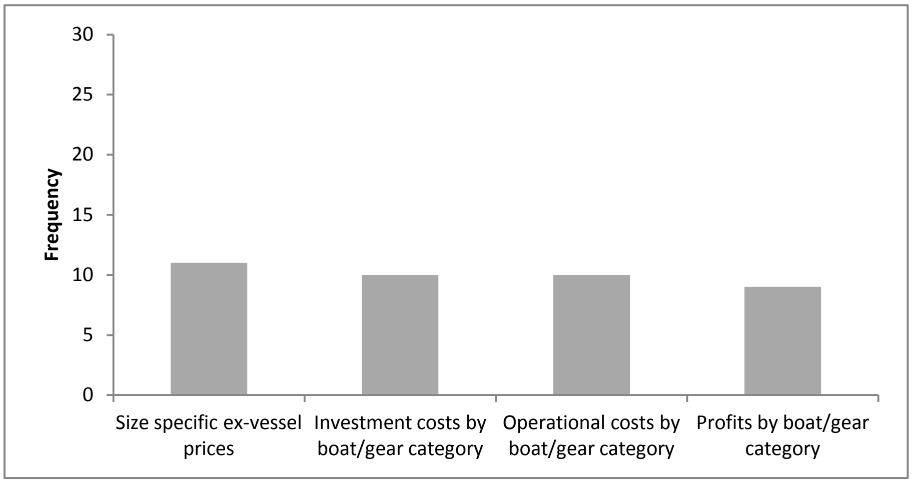

Figure 11: Availability of economic data for the spiny lobster fishery identified by the 30 countries

4.7 Application of Assessment Methods

The eleven groupings of assessment methods provided in the questionnaire were; (i) Virtual Population Analysis (VPA), (ii) Length Cohort Analysis (LCA), (iii) Yield per recruit (Y/R), (iv) Stock-recruitment relationship, (v) production model, (vi) generalized linear model, (vii) time series analysis, (viii) underwater visual census, (ix) tag and recapture studies, (x) ecological approaches (multispecies and ecological models) and (xi) bio-economic approaches (Schaefer-Gordon and Age-Structured).It should be noted that this not an exhaustive list of stock assessment methods and the questionnaire was designed to allow countries to indicate additional methods which have been applied. Assessment methods vary according to the amounts and/or types of data used and these groupings were considered to best capture current and future applications.

Overall, less than half of the countries indicated applications of assessment methods to their spiny lobster fisheries. Length cohort analysis (LCA) was the most frequently identified method (12 countries). Seven countries indicated the application of a virtual population analysis. The applications of stock-recruitment relationship and production model were each identified by six countries. The applications of yield/recruit, time series analysis, bioeconomic model, and underwater visual census were each identified by 5 countries. Four countries indicated the application of tagging studies. Two countries indicated the application of multispecies and ecological models. The application of the generalized linear model was identified by two countries (Figure 12).

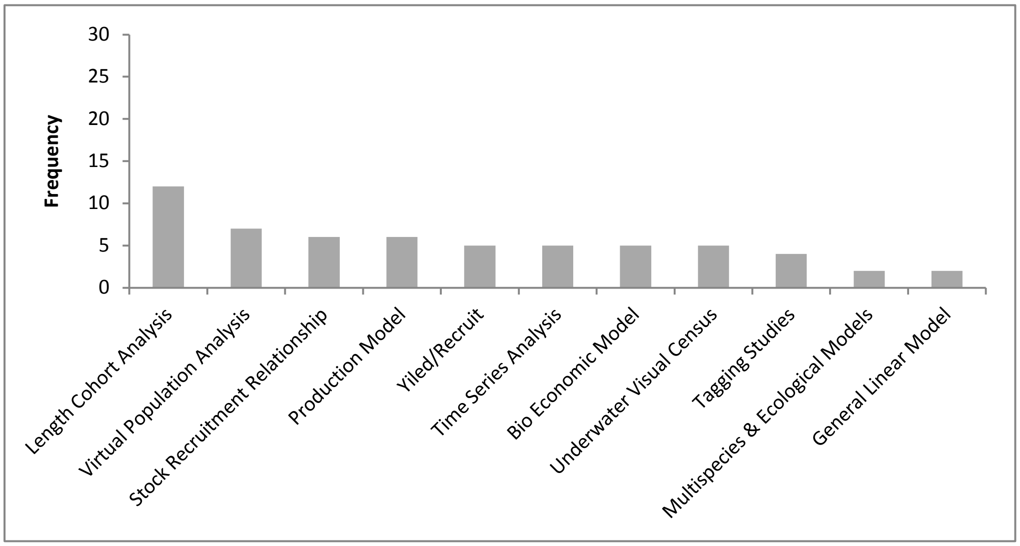

Figure 12: Frequency of methods used to assess the spiny lobster fishery identified by the 30 countries.

5. APPROACHES USED TO CLASSIFY ASSESSMENT METHODS

The classification approach for the various assessment methods used was based on work done by Lleonart, 2002 and ICES, 2012. In this study, three approaches for characterizing assessment methods and their suitability for application to the spiny lobster fisheries in the Western Central Atlantic Area were developed.

5.1 Description, outputs, advantages and limitations of assessment methods

The first approach characterized each method by providing descriptions, outputs; advantages; limitations; and examples of software (Table 2).

Table 2: Assessment methods-descriptions, outputs, advantages, limitations and types of software.

Method	Description	Output	Advantages	Limitations	Software
Virtual Population Analysis (VPA).	VPA reconstructs the past history of the stock in terms of number of individuals and fishing mortalities. The VPA, and its variants, are the most standard and reliable method of stock assessment.	Numbers of individuals and biomass at sea by year and age; Fishing mortality by year, age and operational unit.	Most efficient standard assessment method.	Numerous parameters are required, some of which are assumed and tuning is required.	Lowestoft VPA Suite (Darby & Flatman, 1994) ADAPT (Lassen & Medley, 2001)
Length cohort analysis (LCA)	A modification of VPA (Jones, 1984), which is essentially a VPA on a pseudocohort. LCA can also be performed on the length frequency distribution of the catch.	Numbers of individuals and biomass at sea by age; Fishing mortality by age or length and operational unit	Short data series (even one year) can provide information on stock status.	Invalid assumptions about the pseudocohort could result in biased outputs.	LFDA (Hoggarth *et al.*, 2006) FISAT II-FAO ICLARM Stock Assessment Tool (FAO, 2013 a)
Yield per recruit (Y/R)	Computes the yield that produces one recruit given a particular exploitation pattern (F vector) at different effort intensities.	Yield as function of overall F(or effort) and exploitation pattern (selectivity); Reference points: Y_{MAX}, F_{MAX}, virgin biomass	A general overview of the state of the fishery is obtained as well as reference points which are easy to relate to. Easy to detect growth overfishing and identify management alternatives.	Recruitment rates are a source of major uncertainty.	Thompson and Bell Yield Analysis Using Excel Spreadsheets (FAO, 2013b) Yield (Hoggarth *et al.*,2006)
Stock-recruitment relationship	An approach used to understand the factors driving the recruitment process rather than an assessment method.	Simple visual inspection of scatter plot recruitment vs. stock can show patterns in the current and past situation of the spawning stock and recruitment.	The only way to detect recruitment overfishing.	Inputs are difficult to obtain and can present important biases. It is difficult to differentiate between environmental factors and noise	Yield (Hoggarth *et al.*,2006)

Method	Description	Output	Advantages	Limitations	Software
Production model (also known as global model, surplus production model or catch-effort model)	Estimation of the past and current level of biomass and the state of the stock from the analysis of the relationships between effort and catch.	Carrying capacity (equivalent to Virgin Biomass), catchability and growth rate are obtained. Reference points: MSY and E_{MSY}	Provides a very general view of the current state of the fishery and its history. Easy to relate to and sound reference points.	Application to multi-species fisheries is not suitable given the difficulties of effort allocation or where catchability and selectivity are not uniform.	CLIMPROD (FAO 2013c) CLIMPROD-PLUS (FAO, 2013d) CEDA (Hoggarth *et al*., 2006) BIODYN (Hoggarth *et al*., 2006) ASPIC (Hoggarth *et al*., 2006)
Generalised Linear Model	Examination of the relationship and interaction between dependent and independent variables.	It is possible to relate the dependent variable to the independent variables.	Useful in understanding the relationships between fisheries variables e.g CPUE and environmental or technical variables.	Mainly descriptive	FishStatJ[12] (FAO, 2013e), SPSS
Time series analysis	Examination of a time series of data by trend, seasonality and noise. The use of transfer functions allows relationships between the data and environmental or other external variables to be modeled.	Trend and seasonality of the analysed variable. With additional information, it is possible to relate the behaviour of the dependent variable to other variables (e.g. effects of environment).	Useful for short-term forecasting.	Mainly descriptive and cautious interpretation required.	FishStatJ (FAO, 2013e) FishStat Plus (FAO 2013f)
Ecological Approaches	Several approaches are included in this category e.g. multispecies modeling; multispecies VPA; and methods based on mass balance and food web	Ecological interaction between species, and quantified pathways of matter and energy between the different species. Diet composition, abundance, annual food consumption rate, instantaneous total mortality for species or species	Provides a more realistic representation of the real ecological system better than single species assessments.	A large amount of biological and ecological information is required and many interaction parameters are assumed.	MSVPAX (Garrison *et al*., 2011) EcoPath with EcoSim (Christensen *et al*., 2000)

[12] Global statistical datasets, allows browsing, data mining, charting, grouping and reporting.

Method	Description	Output	Advantages	Limitations	Software
	approaches.	groups defined in the ecosystem, as well as details of fishing such as catches, fishing effort, species composition of the catch by different fleet types.			
Bio-economic approach	This approach includes the population dynamics and the economic structure of fisheries. Schaefer-Gordon and age-structured approaches are two approaches used in the region.	Conditions giving optima according to different criteria or results (e.g. optimum minimum size at capture) Reference points: MSY; MEY	Provides a more realistic approach to fisheries assessments as economic incentives usually drive fishing activities.	Numerous parameters are required, and the complexity of model increases the uncertainties.	Spatial-Space time Dynamics in Marine Fisheries (FAO 2013g) BEAM4 (FAO 2013h)
Underwater visual census	Biomass, distribution and density estimations are obtained from diver surveys.	Species richness and density are obtained as well as mean sizes, mean weights and biomass estimates.	Provides fishery independent abundance estimates and is fast and efficient.	Errors including observation of the target population and sampling may lead to biased results. Highly trained divers are required.	
Tagging	Biomass, growth estimates and movement information obtained by tagging and recapturing/recovering individuals	Biomass estimate, growth rates, age estimates and movement rates are obtained	Provides fishery independent abundance estimates and total mortality.	Tag induced mortality, and uncertainties in tag retention rates, and low tag returns or recovery.	VONBIT 2005 (FAO 2013i)

5.2 Analytical capacity and data requirements by assessment method

The second approach rated methods with scores according to data and analytical capacity requirements, using 5 categories; where [1, 2] = low; [2.5, 3] = moderate; [3.5, 4] = high; and [4.5, 5] = very high. For data requirements, categories were assigned according to the types of data required to conduct the assessment method (Table 3). For analytical capacity, categories were assigned based on knowledge of and experience in various criteria identified as necessary for the completion of the assessment method (Table 4). Figure 13 provides a graphic representation of each assessment method based on the scores and categories assigned for both data and analytical capacity requirements.

Table 3: Assessment methods scored by data requirements

Method	Data Requirements	Score	Category
Virtual Population Analysis (VPA).	Catch-at-age of several years by operational unit; *M* vector; Terminal *F*s; Length-weight relationships; Total catch in biomass by operational unit and year.	4	High
Length cohort analysis (LCA)	Length or age frequency distribution of the catch representing the pseudo-cohort; M vector; terminal Fs; Length-weight relationship; total catch in biomass by operational unit	3	Moderate
Yield per recruit	Fishing mortality vector(F); Natural mortality vector (M); Age-length key or parameters of the growth model	3.5	High
Stock-recruitment relationship	Time series data of spawning stocks and recruitments	4	High
Production model (also known as global model, surplus production model or catch-effort model)	Historical series of catch-effort data (usually on annual basis)	2	Low
Generalised Linear Model	Multivariate data where one variable can be considered dependent on the others e.g. catch, CPUE, effort data.	2	Low
Time series analysis	Data series over an extended time period e.g. catch, CPUE, effort, vessel characteristics.	3	Moderate
Ecological Approaches	In addition to the single species analysis data needs, species interactions are required, including the quantification of predator-prey relationships.	5	Very high
Bio-economic approach (Schaefer-Gordon)	Population dynamic parameters; stock biomass; catch and effort data; economic parameters concerning all aspects of extractive activities (costs, prices, profits, etc).	2.5	Moderate
Bio-economic approach (Age structured)	Population dynamic parameters; stock biomass; catch-at-age of several years by operational unit; *M* vector; terminal *F*s; length-weight relationships; total catch in biomass by operational	4.5	Very high

Method	Data Requirements	Score	Category
	unit and year; economic parameters concerning all aspects of extractive activities (costs, prices, profits,etc).		
Underwater visual census	Number of species within the habitat, survey design; individual size estimates; information on habitat structure; temporal series to allow estimation for trend analysis.	4	High
Tag recapture studies	Individual weight and length; sex ratio; information on area of distribution.	3.5	High

Table 4: Assessment methods scored by analytical capacity requirements

Method	Analytical Capacity	Score	Category
Virtual Population Analysis (VPA).	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. ADAPT, R, SPSS); Age/size structure models (all variants of the VPA)	4	High
Length cohort analysis (LCA)	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. LFDA, R, SPSS); Age/size structure models (Jones' Length Cohort Analysis)	3	Moderate
Yield per recruit	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. Thompson and Bell Yield using Excel, R, SPSS); Age/size structure models	3	Moderate
Stock-recruitment relationship	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. Yield, R, SPSS); Age/size structure models	3	Moderate
Production model (also known as global model, surplus production model or catch-effort model)	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. BIODYN, R, SPSS);	3	Moderate
Generalised Linear Model	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; statistical packages (e.g. R,SPSS, Excel);	2	Low
Time series	Statistics (differential and inferential);survey design and data	2	Low

Method	Analytical Capacity	Score	Category
analysis	collection; statistical analysis of catch/biological/effort data; statistical packages (e.g. R, SPSS, Excel);		
Ecological Approaches	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. Ecopath with Ecosim, R, SPSS);multispecies & ecological models.	5	Very high
Bio-economic approach (Schaefer-Gordon)	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. Schaefer-Gordon Analysis using Excel, R, SPSS); bio-economic models (Schaefer-Gordon)	3.5	High
Bio-economic approach (age structured approach)	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics; derivation of reference points and proxies in fisheries management (e.g MSY, F_{MSY});stock assessment software and statistical packages (e.g. BEAM 4, R, SPSS); Age/size structure models; bio-economic models; multispecies models.	4	High
Underwater visual census	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data;	2	Low
Tag recapture studies	Statistics (differential and inferential);survey design and data collection; statistical analysis of catch/biological/effort data; population dynamics;	2.5	Moderate

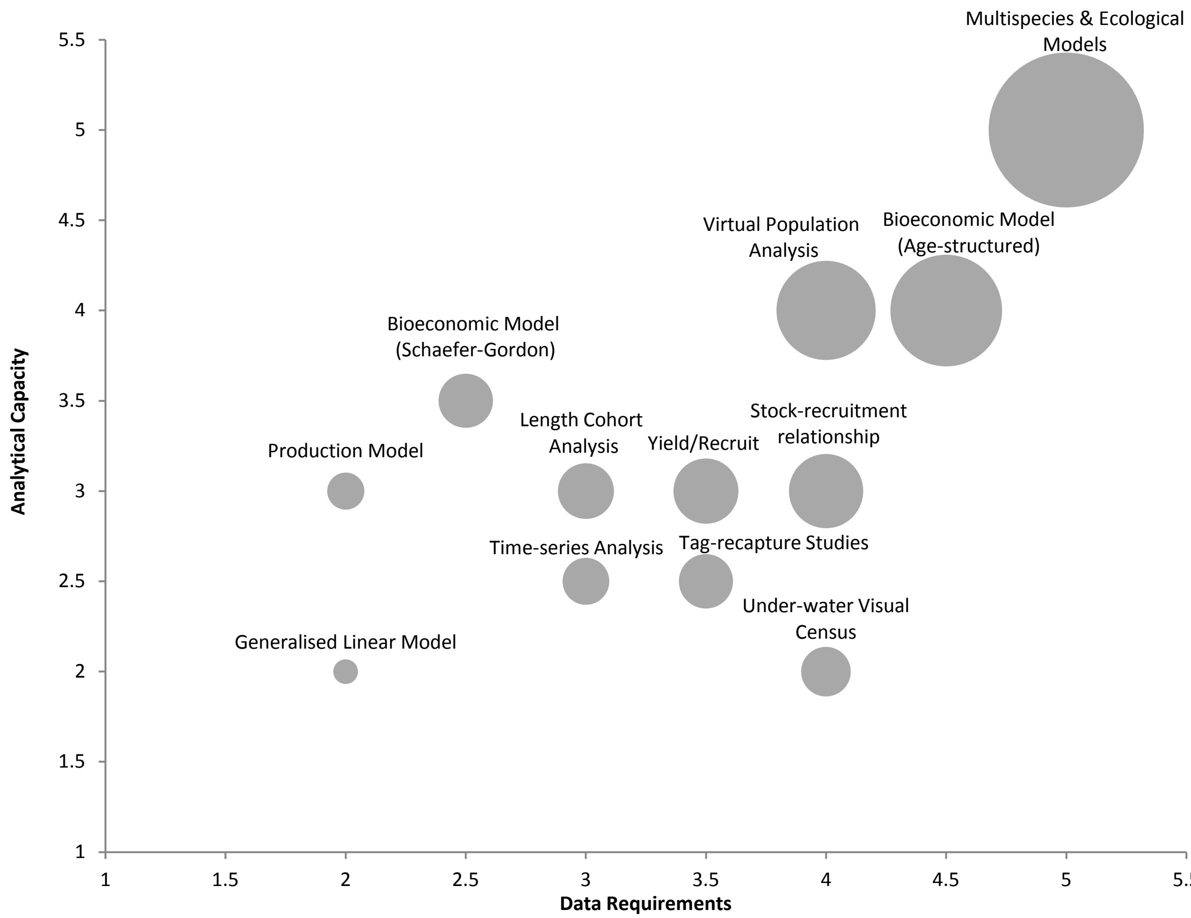

Figure 13: Data and analytical capacity requirements by assessment methods, where [1, 2] = low; [2.5, 3] = moderate; [3.5, 4] = high; and [4.5, 5] = very high

5.3 Suitability of each assessment method by country.

The third approach characterized each method by its suitability for the spiny lobster fishery in the WECAFC area; suitability for countries collecting length frequency data and current applications (Table 5).

Table 5: Assessment methods, suitability for spiny lobster fisheries in the WECAFC area and current applications

Method	**Suitability for Spiny Lobster Fishery in WECAFC Area**	**Suitability for Countries Collecting Length Frequency Data**	**Current Application**
VPA	Suitable even though numerous parameters are required, some of which are assumed and tuning is required.	Suitable	The Bahamas; Belize; Colombia (San Andres y Providencia); Cuba; Mexico; Nicaragua; United States-Florida
Length Cohort Analysis	Suitable given the lack of long historical series available in many of the countries.	Suitable	Antigua and Barbuda; The Bahamas; Belize; Bermuda; Brazil; Colombia (San Andres y Providencial); Cuba; Jamaica; Mexico; Nicaragua; United States-Florida; Venezuela
Yield per recruit (Y/R)	Suitable if the results from an analytical method (e.g. LCA) which provides the required data are available for combination.	Unsuitable	Belize; Brazil; Colombia (San Andres y Providencia); Martinique; Nicaragua
Stock-recruitment relationship	Suitable in countries where good estimations of stock-recruitment are available over many years	Unsuitable	Belize; Colombia (San Andres y Providencia); Cuba; Mexico; Nicaragua; Turks and Caicos Islands
Production model	Suitable for countries which have long historical series of catch and effort data and where spiny lobster is the target fishery.	Unsuitable	Antigua and Barbuda; The Bahamas; Bermuda; Colombia (San Andres y Providencia); Jamaica; Mexico
Time series analysis	Suitable in cases where a long temporal series is available.	Suitable	Antigua and Barbuda; Bermuda; Brazil; Turks and Caicos Islands; United States-Florida
Generalised Linear Model	Suitable for analysing the types of data generally available in most countries	Suitable	Antigua & Barbuda; Brazil
Bio-economic Approaches	Suitable for countries which have a long time series of catch and effort data, biological, and economic data.	Suitable	Antigua & Barbuda; Colombia (San Andres y Providencia); Cuba; Jamaica; United States-Florida
Ecological approaches	Suitable for countries which have extensive biological and ecological data as well as	Unsuitable	Colombia (San Andres y Providencia); Panama

Method	Suitability for Spiny Lobster Fishery in WECAFC Area	Suitability for Countries Collecting Length Frequency Data	Current Application
	interactions between species.		
Underwater visual survey	Suitable for countries which have habitat information (e.g maps, satellite imagery etc.)	Suitable	Antigua & Barbuda; Colombia (la Guajira); Guatemala; Mexico; United States-Florida
Tag-recapture studies	Suitable for countries with the resources (financial and human) to implement the programme and monitor tag recapture/recovery.	Suitable	Antigua & Barbuda; Bermuda; St. Kitts and Nevis; United States-Florida

6. SUMMARY OF ASSESMENT METHODS

A summary of each assessment method is provided below. The summaries are useful for organizing information about available approaches and provide a guide to assist the OSPESCA/WECAFC/CRFM/ CFMC Working Group on Spiny Lobster in the selection of the most appropriate methods to consider for assessment of their stocks.

6.1 Virtual Population Analysis

VPA reconstructs the past history of the stock in terms of number of individuals and fishing mortalities. Many variants of the VPA exist, and examples include; separable VPA (Pope & Shepherd, 1982), extended survivors analysis (Shepherd, 1999) and ADAPT (Lassen & Medley, 2001). The method requires catch-at-age of several years by operational unit; natural mortality (M) vector; terminal fishing mortality (Fs); length-weight relationships; total catch in biomass by operational unit and year. Total catches at age is usually obtained from large scale length-frequency sampling and supplemented by age-length keys. High analytical capacity is required. An example of software for this method is ADAPT, Lassen & Medley (2001). The outputs obtained include: numbers of individuals and biomass by year and age; and fishing mortality by year, age and operational unit. Virtual population analysis is considered to be the most efficient standard assessment method. However its limitations include: the need for numerous parameters, many of which are assumed: and the need for tuning with auxiliary data such as biomass indices or CPUE indices. The VPA is only suitable for countries which have the required data. In the case where countries have been collecting length frequency data, a virtual population analysis could be applied. The countries which indicated the use of the virtual population analysis include The Bahamas(CRFM, 2007; CRFM, 2008; CRFM, 2009); Belize (FAO, 2009; Gongora, 2010); Colombia (San Andres y Providencia); Cuba (Puga *et al*., 2013); Mexico (Zetina-Moguel& Ríos-Lara, 1998; Ríos Lara *et al*., 2000; Ríos Lara & Salas 2009; Ríos Lara *et al*., 2012); Nicaragua (FAO, 2009); and the United States-Florida (Butler *et al*., 2003).

6.2 Length Cohort Analysis

The length-structured VPA or length cohort analysis is a modification of the VPA (Jones, 1984). This approach requires the length frequency distribution of the catch. The outputs include length frequency distribution of the catch representing the pseudocohort; M vector; terminal Fs; length-weight relationship; total catch in biomass by operational unit. The analytical capacity required is moderate. Examples of software include LFDA (Hoggarth *et al*., 2006) and FISAT II-FAO ICLARM Stock Assessment Tool. The main outputs include: numbers of individuals and biomass by length; and fishing mortality by length and operational unit. The advantage of this method is that short data series (even one year) can provide information on stock status. LCA is considered to be particularly suitable in situations where only short time series of spiny lobster length frequency data exist. Countries which have length frequency data and have not already applied this analysis could do so. Countries which have applied this method include: Antigua and Barbuda; The Bahamas (CRFM 2005, 2006, 2007, 2008, 2009); Belize (Gongora, 2010); Bermuda (Government of Bermuda, 2012); Brazil; Colombia-San Andres and Providencial (Borda& Cruz, 2007); Cuba; Honduras (WWF-USAID, 2010a), Jamaica; Mexico(Zetina-Moguel& Ríos-Lara, 1998; Sosa-Cordero *et al*., 1996) ; Nicaragua (Barnutty, 2011); United States-Florida (Muller *et al*., 1997); and Venezuela (Arocha-Perez, 2012).

6.3 Yield/Recruit

Yield per recruit models predict the average relative catch available from a single recruit to the fishery at different levels of fishing mortality, *F*. The data requirements include: fishing mortality vectors (F); natural mortality vector (M); and age-length key or parameters of the growth model. The analytical capacity required is moderate. Thompson and Bell Yield Analysis Using Excel Spreadsheets (FAO, 2013) and Yield (Hoggarth *et al*., 2006) are examples of software which could be applied. The outputs include yield as function of overall F (or effort) and exploitation pattern (selectivity and fishing season); as well as reference points e.g (Y_{MAX}, F_{MAX} and virgin biomass). The advantages of this approach are that a general overview of the state of the fishery is obtained as well as reference points which are easy to relate to. The occurrence of growth overfishing, where too many organisms are caught before the cohort has reached its maximum biomass can also easily be detected. However this approach assumes constant recruitment to the stock each year regardless of fishing pressure and this is a source of major uncertainty. Yield per recruit analysis is applicable for countries which already have outputs from VPA or LCA methods. Countries which currently have length frequency data, but have not assessed them can apply a LCA and then attempt a yield per recruit analysis. The countries which have applied this method include Belize (FAO, 2009; Gongora, 2010), Brazil (Cruz and Borda, 2013), Colombia-San Andres and Providencia (Borda & Cruz, 2007); Martinique; Nicaragua (FAO, 2009) and United-States (Acosta *et al*., 1997).

6.4 Stock Recruitment Relationship

The stock recruitment relationship is an approach used to understand the factors driving the recruitment process rather than an assessment method. It requires a time series of spawning stock and recruitment relationships. The analytical capacity required is moderate. There are many models e.g. Beverton and Holt and Ricker, which can fit stock and recruitment data. However, even simple visual inspection of a scatter plot of recruitment vs. spawning stock can show current and past patterns. The stock-recruitment relationship is the only way to detect recruitment overfishing (overfishing on spawning stock leading to a decreasing proportion of older fish in the catch, and hence very low recruitment year after year). However, the inputs are difficult to obtain and can present important biases. It is also difficult to differentiate between environmental factors and noise, and these uncertainties should be taken into account. This approach is suitable in countries where stock-recruitment estimations are available over many years and where countries have conducted some type of LCA or VPA. Countries which have utilized this approach include: Belize (FAO, 2009; Gongora, 2010); Colombia (San Andres y Providencia); Cuba (Puga *et al*., 2013); Honduras (WWF-USAID, 2010a), Mexico (Ríos-Lara *et al.*, 2000; González-Cano *et al*., 2001; Nicaragua (FAO, 2009); and Turks and Caicos Islands.

6.5 Production Model

The production model is also known as surplus production model, biomass dynamic model or catch-effort model. This approach provides an estimation of the past and current level of biomass and the state of the stock from the analysis of the relationships between effort and catch. The Schaefer model (Schaefer, 1954), the Fox model (Fox, 1970) and the Pella and Tomlinson model (1969) are examples of production models. These methods use undifferentiated biomass (or numbers in some models), not subdivided between ages or lengths, to estimate the total size of the fish stock aggregated across all the ages that are caught (Hoggarth *et al*., 2006). Production models require a historical series of catch-effort data (usually on annual basis). The analytical capacity required is moderate. CLIMPROD; CLIMPROD-PLUS; CEDA; BIODYN; and ASPIC are examples of software which can be used. The outputs include carrying capacity (equivalent to virgin biomass), catchability and growth rate. The reference points that can be obtained include, MSY and EMSY. This approach provides a very general view of the current state of the fishery, its history, and reference points which are sound and can be easily related to. However, application to multi-species fisheries is not appropriate suitable given uncertainties in effort allocation, catchability and selectivity. This method is suitable for countries which have long historical series of catch and effort data and where spiny lobster is the target fishery. This method is not suitable for the analysis of length frequency data. The countries which have applied this method include Antigua and Barbuda; The Bahamas (CRFM, 2006, 2007, 2008 & 2009; Medley & Gittens; in prep, Muller & Puga, in prep); Bermuda (FAO, 2001); Colombia-San Andres and Providencia (Borda & Cruz, 2007); Jamaica; Mexico (Zetina-Moguel & Ríos-Lara, 1998; Arce *et al*., 2001; Ríos-Lara, 2012), and the US-Florida (Milon, 1998).

6.6 General Linear Model

This approach examines the relationship and interaction between dependent and independent variables. This approach is described in (McCullagh and Nelder, 1989). It requires multivariate data where one variable can be considered dependent on the others e.g. CPUE. The analytical capacity required is low. The advantage of this method is that it is possible to relate the dependent variable to the independent variables and it is therefore useful in understanding the relationships between fisheries variables e.g. CPUE and environmental or technical variables. However, the results are mainly descriptive. The Generalized Linear Model is suitable for analysing the types of data generally available in most countries and can be applied to countries which have length frequency data. The countries which have indicated the use of this method are Antigua & Barbuda; and Brazil (Cruz and Borda, 2013).

6.7 Time Series Analysis

Time series analysis involves the examination of a time series of data by trend, seasonality and noise and has been described by Box and Jenkins (1976). The use of transfer functions allows relationships between the data and environmental or other external variables to be modelled (Rotschild *et al*., 1996). Long time series of data are required (e.g. catch, CPUE, effort, vessel characteristics). The analytical capacity required is low. Examples of software include FishStatJ–software for fishery statistical time series, and FishStat Plus-Universal software for fishery statistical time series. The outputs of these software are highly dependent on the quality of data provided by the countries. The outputs of time series analysis include trend and seasonality of the analysed variable, and with additional information; it is possible to relate the behaviour of the dependent variable to other variables (e.g effects of environment). Time series analysis is useful for short-term forecasting rather than assessment purposes as it is mainly descriptive and cautious interpretation is required as the stock abundance and the effects of fishing cannot be quantitatively determined. This type of analysis is only suitable in cases where a long temporal series is available and can be applied to length frequency data.The countries which have applied this method include: Antigua and Barbuda; Bermuda (FAO, 2003); Brazil; Turks and Caicos Islands and United States-Florida.

6.8 Ecological Approach (Multispecies and Ecological Models)

There are several approaches within this category and they include: multispecies modeling (Rose *et al*., 1996); multispecies VPA (Sparre, 1991, Magnusson, 1995); and methods based on mass balance and food web approaches (Pauly *et al*., 2000). The data requirements for this approach are high because in addition to the single species analysis data needs, species interactions are required, including the quantification of predator-prey relationships. Very high analytical capacity is also required to apply these approaches.

EcoPath with EcoSim is an example of software which models ecological and ecosystem interactions (Christensen *et al*., 2000). The outputs of this approach include ecological interaction between species, and quantified pathways of matter and energy between the different species. These types of approaches provide a more realistic representation of the real ecological system than single species assessments. However, a large amount of biological, technological and ecological information is required and many interaction parameters are assumed. These types of approaches are suitable for countries which have extensive data available. The approaches are not suitable for the analysis of length frequency data. The countries which have applied these models include Colombia (San Andres y Providencia) (Borda& Cruz, 2007) and Panama (Guzmán *et al*., 2004).

6.9 Bioeconomic Models

This approach estimates the bioeconomic impact derived from different management strategies. The approaches include the static and dynamic versions of the Gordon-Schaefer (Gordon, 1953, 1954) model; age-structured dynamic bioeconomic models (Sanchimico and Wilen, 2001; Wilen, 2003) and spatial models (Seijo *et al*., 2004, Seijo and Caddy, 2008). Population dynamics and fleet dynamics are required, as well as cost and benefit data of the fleet. In the case of age structured and spatial models, age data, gear selectivity and spatial data are also required. The analytical capacity required for the Schaefer-Gordon approach is moderate whereas the analytical capacity required for the age-structured approach is high. Examples of software include: Spatial-Space time Dynamics in Marine Fisheries models (ALLOC, YAREA & CHART), and BEAM4. The outputs of these approaches include optima according to different criteria or results (e.g optimum minimum size at capture) and reference points such as F_{MSY}; F_{MEY}. The advantage of a bioeconomic approach is that the output obtained also takes into account the economic incentives driving the fishery in combination with the biological factors of the resource. However, bioeconomic models require a greater number of parameters, and the complexity of model increases the uncertainties. Bioeconomic models are suitable for countries which have a long time series of catch and effort data; economic data; and completed a production model. In cases where countries have length frequency data which can be related to age, they can be used in the implementation of an age structured-bioeconomic approach. The countries which have utilized bioeconomic models include Antigua & Barbuda, Colombia (San Andres y Providencia) (Borda& Cruz, 2007), Cuba, Jamaica, Mexico and the United States-Florida (Milon *et al*., 1998; Shivalani *et al*., 2004; Shivlani, 2010).

6.10 Underwater Visual Survey

This approach provides a variety of variables including biomass abundance estimates, size estimates, distribution and density estimations, species composition and habitat characteristics. There are many techniques used to count the organisms and estimate the density (number or weight) for the entire study area. This approach requires a robust survey design; as well as detailed knowledge on habitat structure. The availability of temporal series allows trend analysis. The analytical capacity required is low. Species richness and density are obtained as well as mean sizes, and biomass estimates. This approach is useful as it provides fishery independent abundance estimates and is fast and efficient. Drawbacks which must be taken into consideration include observation errors of the target population due to distribution of individuals in time and space: differences associated with habitats, species behaviour and activity; diver behaviour and efficiency and an inaccurate sampling design. The distribution of adult spiny lobster in deep water habitat makes this section of the population inaccessible to visual census surveys. These surveys require highly skilled divers who are trained in survey methods. Underwater visual surveys are suitable for countries which have habitat information (e.g. maps, satellite imagery etc.) and the personnel. Countries which have length frequency data could compare them to the size estimates obtained from underwater surveys and combine the data where possible. Countries which have used this approach include Antigua & Barbuda, Colombia (la Guajira) (AUNAP-ECOSFERA, 2012), Guatemala (MASPLESCA, 2012), Honduras (WWF-USAID, 2010b), Mexico (Ríos-Lara *et al*., 1998; Ríos-Lara *et al*., 2003; Bello, 2005; Ríos-Lara *et al*., 2007; Ríos-Lara, 2009) and United States-Florida (Cox *et al*. 2003).

6.11 Tag-Recapture Studies

In tagging studies, organisms are captured, measured tagged and released. Tagging can provide information on biomass abundance, age and growth estimates and movement patterns. Tags can either be recaptured in an independent fishery programme or recovered from a fisheries dependent programme. The data requirements include individual weight and length for tagged individuals; sex ratio; knowledge on the area of distribution; robust sampling design, and a recapture or recovery programme. The analytical capacity requirements are moderate. VONBIT 2005- Von Bertalanffy Iterative Approach is an example of software which can be used to analyse data from a tag recapture/recovery programme. The outputs of tagging studies include biomass abundance estimates, length frequency, growth rates and age estimates: and movement patterns. The advantage of this method is that it provides abundance estimates which are fishery independent. However, the drawbacks include tag induced mortality; reduction of growth rates in tagged individuals; uncertainties in tag retention rates as a result of moulting and differences between juvenile stages; and low tag returns or recovery. The implementation and monitoring of these studies also require skilled personnel. Tagging studies are suitable for countries which have the resources available to implement the programme and monitor tag recapture/recovery. Countries which have length frequency data could combine them with those obtained from tagging studies where possible and conduct for length based analyses. The countries which have conducted these studies include Antigua & Barbuda, Bermuda (Luckhurst *et al*., 2002), St. Kitts and Nevis, and United States-Florida (Lyons *et al*., 1991).

PART II: A PROPOSAL FOR A COMMON SURVEY AND STOCK ASSESSMENT METHODOLOGY FOR CARIBBEAN SPINY LOBSTER FOR APPLICATION IN THE WECAFC AREA AND WAYS TO INCORPORATE THE PRIVATE SECTOR

7. PROPOSED COMMON ASSESSMENT METHODS AND THE INCORPORATION OF THE PRIVATE SECTOR IN DATA COLLECTION

The results of this study show that there is a wide variation in the availability of data and application of assessment methods throughout the WECAFC countries. This variation is the result of a combination of the following factors:

i) the management objectives and strategies for the spiny lobster fishery;

ii) the scale of the spiny lobster fishery;

iii) the human and financial resources available for data collection;

iv) the quality and availability of data;

v) the analytical capacity available to conduct assessment methods.

In order to generate appropriate management advice, a good basic data collection system based on sampling techniques specific to the country and fishery is required. The collection of basic data on catches, fishing effort, and prices as well as detailed data on fishing vessels, gear and operations; biological and economic data from sampled-based fishery surveys conducted on a regular basis are an important source of fishery information (Stamatopoulous, 2002). These data, when collected periodically with an appropriate survey design, form the basis of robust stock and fishery assessment. Hoggarth *et al.* (2006) highlight that only data which would contribute directly to the management process should be collected on a routine basis as a critical concern for data collection is consistency. In many cases, it is imperative to have long time series of data collected consistently in order to evaluate trends. However many countries do not have long time series of data. This is especially the case for economic and biological data which are usually collected on an ad hoc basis in many countries.

In developing a common assessment method for the spiny lobster fisheries in the WECAFC area, the life history, wide distribution of adults, and limited data collection programmes must be taken into account. It is therefore important to consider a variety of complementary methods which would allow countries to choose the method best suited to their current fishery situation. As seen in the previous sections, approaches can range from quantitative procedures applicable in data-poor situations to the multi-species and ecological models which are constantly being improved to include more factors (e.g. environmental factors and climate change).

Based on the data available, the assessment methods currently used in the WECAFC area, and the analytical capacity required, the length cohort analysis and virtual population analysis are proposed as common methodologies. Even though it has been criticised (Hilborn and Walters, 1992) the usefulness of length cohort analysis is recognised in cases where aging the organism is difficult (e.g. lobsters and other crustacea), or where length frequency data already exist, especially if they are the only data available (Hoggarth *et al*., 2006).The application of a cohort technique based on size, Jones (1984), has also been recommended under the MASPLESCA project (OPESCA, 2012).

The results indicate that countries can be divided into four categories: i). countries which do not have length frequency data; ii) countries which have length frequency data but have not applied a LCA or VPA; iii) countries which have length frequency data and have only applied a LCA; and iv) countries which have length frequency data and have applied both a LCA and a VPA.

In Table 6, general recommendations for the implementation of the length cohort analysis and virtual population analysis are made for each of the categories listed above and the associated countries.

Table 6: The status of countries regarding the availability of length frequency data, application of LCA or VPA analyses and recommendations.

Status	Countries	Recommendation
i. Countries which do not have length frequency data.	Anguilla Dominican Republic Grenada Haiti Montserrat St. Lucia St. Vincent & the Grenadines Trinidad & Tobago	1. Development of a sampling programme for the collection of length frequency data in collaboration with the fisheries authorities, the processing companies and industrial and artisanal fleets; 2. Conduct training in survey design and sampling programmes for the collection of length frequency data. 3. Collection of at least one year of length frequency data; 4. Identification and application of a suitable software to analyse length frequency data for stock assessment purposes (e.g. LFDA (Hoggarth *et al*., 2006) or FISAT II (FAO, 2013)); 5. Conduct training in the use of statistical methods and the chosen software.
ii. Countries which have length frequency data but have not applied a LCA or VPA.	Colombia (la Guajara) Costa Rica Guadeloupe Guatemala Honduras Martinique Panama Saba St. Eustatius St. Kitts & Nevis Turks & Caicos	1. Application of LCA if the length frequency data are available for less than 10 years. 2. Application of a VPA if the length frequency data are available for (≥10-15 years). 3. Conduct training in the use of statistical methods and the chosen software.

	Islands	
iii. Countries which have length frequency data and have only applied a LCA.	Antigua & Barbuda Bermuda Brazil Jamaica Venezuela	1. Application of a VPA if the length frequency data are available for (≥10-15 years). 2. Conduct training in the use of statistical methods and the chosen software.
iv. Countries which have length frequency data and have applied both a LCA and a VPA.	The Bahamas Belize Colombia (San Andres & Providencia) Cuba Mexico Nicaragua USA-Florida	1. Application of more detailed assessment methods should be applied if the data are available.

In cases where countries do not consider the implementation of LCA or VPA feasible at this time or where length frequency cannot be collected, catch models are recommended. Catch models should only be used on a temporary basis until direct information on stock status and/or trends can be obtained. These models do not use fishery biology functions and parameters and the minimum data required are catch. The Depletion Corrected Average Catch (DCAC) (MacCall, 2009) is an example of this model and can be used to determine whether the recent average catch is sustainable or not. Stock biomass using CPUE abundance indices and catchability coefficients (q) using the following equation: $B_t = CPUE_t / q$ should also be calculated.

8. DATA COLLECTION AND PRIVATE SECTOR INVOLVEMENT

In order to improve data availability and apply the proposed length cohort analysis methodology, the cooperation of the private sector in the data collection process is critical. In cases where logbooks, landings records and market records are not available, the processing sector may provide a source of reliable information. Private sector involvement can be split into two categories: i) lobster fleets (artisanal and industrial) and ii) the processing sector.

Private sector involvement in the provision of data can be voluntary or compulsory. If voluntary, the responses will depend on the level of co-operation between the private sector and the fisheries authorities. If compulsory, legislation is required and can be drafted in various forms, e.g Companies or Statistics Acts (Hoggarth *et al*., 2006). Management plans prepared under the FINNPESCA project (FAO, 2009) and the MASPLESCA project (OPESCA, 2012) also set out guidelines for the types of data which can be collected in collaboration with the private sector. Data collection forms have also been developed for the collection of data from fleets and processors under the MASPLESCA project. It will be necessary for each country to develop forms specifically suited to the spiny lobster harvesting and processing situations in each country.

In setting up a data programme in collaboration with the private sector and to obtain accurate estimates for the application of raising factors, sampling of all categories (e.g. whole lobsters, tails and live lobsters) will be necessary. Therefore, a country specific robust sampling design will need to be developed. Countries will also need to determine which types of data would require direct sampling by the Fisheries Authority and which information could be supplied directly from the private sector. In situations where information will be supplied directly by the private sector a system to validate and verify accuracy will need to be implemented. This could be achieved through direct observation by fisheries authorities at specified time intervals, cross-checking landing records and market records or a combination of these activities.

Data which the private sector can contribute include:

a.) Total landings of spiny lobster; landed weights by boat; fishing location information; and fishing effort: number of fishing units (e.g. traps, divers, nets, lobster aggregating devices), duration of fishing trips (separated by search time and fishing time) or fishing hours per fishing unit.

b.) Classification by weight, size and product type (whole, tails, or live); sex and maturity and length (carapace or tail).

c.) Ex-vessel price; market prices (national and international); cost and earnings; production volume; value of production; and number of jobs generated.

In order to achieve successful incorporation of the private sector into data collection activities, awareness and training programmes will need to be established. The programmes should be developed jointly among the fishers, processors, scientists and managers and should:

i) develop an understanding and appreciation for the importance of data and how it contributes to the sustainable management and use of the spiny lobster resource over the long term,

ii) provide training in methods data collection and reporting,

iii) highlight the associated benefits of a well managed spiny lobster fishery including: improved resource and habitat health; increased profitability of the fishery; and a continuous supply of spiny lobster in the future.

PART III: RECOMMENDATIONS FOR THE DEVELOPMENT AND IMPLEMENTATION OF A COMMON SURVEY AND STOCK ASSESSMENT METHODOLOGY FOR CARIBBEAN SPINY LOBSTER AND CONCLUSIONS FOR IMPORVED MANAGEMENT OF THE FISHERY IN THE WECAFC REGION

9. RECOMMENDATIONS

The main recommendations resulting from this study are summarised in the following sections.

9.1 Fishery -Dependent Information

Accurate and comparable landings are the principal data needed to assess the impact of fishing on spiny lobster populations. The quality of current landings data is not consistent spatially or temporally. It is therefore recommended that:

1. A move towards standardized mandatory reporting of landings data resource-wide be undertaken to improve the data availability and comparability.

9.2 Fishery-Independent Information

Current methods of monitoring the distribution and abundance of spiny lobster independent of the fishery (e.g. underwater visual census and tagging) are limited in area, habitat, the number of organisms sampled (inaccessibility of deep water habitats or low number of tag returns), and frequency. It is therefore recommended that:

1. Consistent techniques that monitor distribution and abundance of lobster independent of the fishery be developed. Additional methodologies should be investigated that cover a wider range of sizes and habitats. These could include modifications in trap design and deployment, the use of remotely operated vehicles (ROV) to carry out surveys on deep water populations: Puerili, larvae and juvenile settlement surveys should also be conducted to facilitate the development of recruitment indices.

9.3 Involvement of the Private Sector in Data Collection

It is recommended to jointly establish awareness and capacity building programmes among fishers, processors, scientists and managers to:

1. Raise awareness about the importance of stakeholder support and participation in data collection and how it contributes to improved management and use of the spiny lobster resource.
2. Provide training in data collection methods, and reporting of data.

3. Allow exchange of knowledge and information among fishers, processors, scientists and managers.

9.4 Development of Assessment Methods

The length cohort and VPA models are considered to be the "best methods" for common application. ICES (2012) states that "long-term success in application of the best methods is an iterative, multi-step process." These steps should involve:

1. Identification of the current set of available methods;
2. Guidance in the selection of the most appropriate methods for a particular application;
3. Education and access to expert information regarding method usage;
4. Encouragement for further testing and development of methods to align with particular management needs and take advantage of advances in statistical theory, computing power, and new knowledge.
5. As countries develop their collection programmes and more data become available, future considerations could incorporate ecosystem and environmental information into stock assessments, such as predator/prey interactions and community structure, climatic shifts in ocean currents and temperature, ocean acidification and diseases caused by toxins and pathogens (e.g the *Panulirus argus* virus 1, Pav1).

9.5 Implementation of Regional Assessment Methods

Currently, 22 out of 30 countries indicated the availability of length frequency data. It is suggested that a common adoption of a stock assessment strategy be developed in phases.

1. Countries which do not collect length frequency data, should implement a data collection system for doing so. In the mean time, these countries could calculate stock biomass using CPUE abundance indices and catchability coefficients (q) as follows $B_t=CPUE_t/q$ as well as utilize catch models to assess their fisheries
2. Countries with at least one year of representative length frequency data should estimate the stock biomass using the LCA method.
3. Countries with a sufficiently long length-frequency time series (≥10 -15 years) should estimate the stock biomass using VPA methods.
4. Undertake a capacity building strategy for WECAFC countries to have an adequate data collection system in place for their lobster fishery with intra and inter annual analysis of length frequency data of the catch, total catch and fishing effort associated with the catch and reported for the different fishing methods used.

5. Undertake capacity building for countries to apply appropriate software for length cohort analysis and VPA stock assessment.

9.6 Regional Investigation of Spiny Lobster Stock Status by the OSPESCA/WECAFC/CRFM/ CFMC Working Group

It is recommended that the joint working group should:

1. Meet annually to assess the status of the spiny lobster stock biomass in the Western Central Atlantic area. Given the transboundary nature of this metapopulation, the joint assessments should also take into account the source-sink configuration of larvae production and settlement.
2. Recommend corresponding harvest control rules for spiny lobster fisheries operating throughout the WECAFC area based on the outputs of these assessments.

10. CONCLUSION

Given the transboundary nature of this metapopulation, the following management and use practises, if implemented at the local levels would also benefit the spiny lobster fishery as a whole within the WECAFC area:

1. Protection of the habitats of the various life cycle stages for *P. argus* (mangroves, seagrass meadows, and the structural complexity of coral reef areas);
2. Increasing the use of species friendly gear;
3. Compliance with the regional minimum size restrictions;
4. Protection of the spawning and berried individuals;
5. Closure of reproductive source areas to fishing noting the difficulty associated with this move towards spatial management;
6. Limiting fishing effort at current levels in the entire area by controlling the number of boats authorised to fish, as well as specifying the number of fishing days per boat for each fishing season;
7. Establishment of complementary harvest control rules for spiny lobster fisheries throughout the WECAFC area.

PART IV: REFERENCES AND APPENDICES

11. References

Arce, A.M., Aguilar,W., Sosa, E., Caddy, J.F. (1997) Artificial shelters (casitas) as habitats for juvenile spiny lobster *Panulirus argus* in the Mexican Caribbean. Mar. Ecol. Prog. Ser. 158, 217–224

Baisre, J.A., Cruz, A.R., 1994. The Cuban spiny lobster fishery. In: Phillips, B.F., Cobb, J.S., Kittaka, F. J. (Eds.), Spiny Lobster Management. Blackwell Scientific Publications/Fishing News Books, London/Oxford, pp. 119–132.

Box, G. E. P. and Jenkins, G. M. (1976), Time Series Analysis: Forecasting and Control, San Francisco: Holden-Day.

Box, S. (2013) A review of the spiny lobster fisheries of the Honduran Caribbean. Spatial Ecology of Fisheries and Marine Protected Areas Program Smithsonian Institution, National Museum of Natural History. 49 p.

Brock, V. E. (1954) A Preliminary report on a method of estimating reef fish populations. Journal of Wildlife Management, 18(3):297-308

Butler, M.J., Herrnkind,W.F., Hunt, J.H., 1997. Factors affecting the recruitment of juvenile Caribbean spiny lobsters dwelling in macroalgae. Bull. Mar. Sci. 61, 3–19.

Christensen, V., Walters, C. J., Pauly, D. (2000) Ecopath with Ecosim: A User´s Guide, October 2000 Edition. Fisheries Centre, University of British Columbia, Vancouver, Canada and ICLARM, Penang, Malaysia

Cochrane, K.L.**(**2002) A fishery manager’s guidebook. Management measures and theirapplication. FAO Fisheries Technical Paper No. 424. Rome, FAO. 231 pp.

Cochrane, K., Tandstad, M., Cruz, R., Ehrhardt, N.M., González, J., Medley, P., Restrepo, V.R., Seijo, J.C. (2001) Management: review of existing regulations, report on the assessment of the Caribbean spiny lobster (*Panulirus argus*). FAO Fish. Rep. 619, 136–154.

Chakalall, B. and Cochrane, K. (2007) Regional Cooperation for the Responsible Use of the Caribbean Spiny Lobster Resource. Proceedings of the 60th Gulf and Caribbean Fisheries Institute. 60, 239-246.

CRFM 2005. Report of the First Annual CRFM Scientific Meeting. CRFM Fishery Report No. 11. 318p.

CRFM 2006. Report of Second Annual Scientific Meeting – Port of Spain, Trinidad and Tobago, 13-22 March 2006. CRFM Fishery Report - 2006, Volume 1.188 p.

CRFM. 2007. CRFM Fishery Report-2007. Volume 1. Report of the Third Annual Scientific Meeting-St. Vincent and the Grenadines, 17-26 July 2007. 183 pp.

CRFM.2008. CRFM Fishery Report-2008. Volume 1. Report of the Fourth Annual Scientific Meeting- Kingstown, St. Vincent and the Grenadines, 10-20 June 2008. 219 p.

CRFM. 2009. CRFM Fishery Report-Volume 1. Report of the Fifth Annual Scientific Meeting- Kingstown, St. Vincent and the Grenadines, 09-18 June 2009. 167p.

CRFM. 2011. CRFM Fishery Report-Volume 1. Report of the Seventh Annual Scientific Meeting- Kingstown, St. Vincent and the Grenadines, 16-24 June 2011. 181p.

Cruz, R., León, M.E., Puga, R., (1995) Prediction of commercial catches of the spiny lobster *Panulirus argus* in the Gulf of Batabanó. Crustaceana 68, 238–244.

Cruz, R. (2002) Manual de métodos de muestreo para la evaluación de las poblaciones de langostaespinosa. FAO Documento Técnico de Pesca. No. 399. Roma, 43p.

Darby, C.D. and Flatman, S., (1994). Virtual Population Analysis: Version 3.1 (Windows/DOS), User Guide. Inf. Techn. Ser., MAFF Direct. Fish. Res., Lowestoft (1): 85 pICES(2012) Report on the Classification of Stock Assessment Methods developed by SISAM. ICES CM 2012/ACOM/SCICOM:01. 15 pp.

Ehrhardt, N.M., Puga, R., Butler, M.J. IV (2010) In: Fanning, L., Mahon, R., McConney, P., editors. Towards Marine Ecosystem-Based Management in the Wider Caribbean. Amsterdam, NL: Amsterdam Univ. Press, 157–175.

Lewis, J.B., Moore, H.B., Babis, W., (1952) The post-larval stages of the spiny lobster Panulirus argus. Bull. Mar. Sci. Gulf Caribb. 2, 234–337.

Lleonart, J. (2002) Overview of stock assessment methods and their suitability to Mediterranean fisheries.5th Session of the SAC-GFCM, Rome, 1-4 July.

FAO (1999) Indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries.No. 8. Rome, FAO. 1999. 68 pp.

FAO (2003) Report of the second Workshop on the Management of Caribbean Spiny Lobster Fisheries in the WECAFC Area. Havana, Cuba, 30 September – 4 October 2002. FAO Fisheries Report No. 715. Rome 273 p.

FAO (2007) Report of the fifth Regional Workshop on the Assessment and Management of the Caribbean Spiny Lobster. Mérida, Yucatán, Mexico, 19–29 September 2006. FAO Fisheries Report No. 826. Rome, 99p.

FAO (2009) PROYECTO GCP/RLA/150/SWE – FIINPESCA Fortalecimiento de la Investigación Pesquera Interdisciplinaria para la Pesca Responsable en los Países del Istmo Centroamericano.

FAO (2013a) FISAT II - FAO-ICLARM Stock Assessment Tool. http://www.fao.org/fishery/topic/16072/en. October 14, 2013

FAO (2013b) Thompson and Bell Yield Analysis Utilising Excel Spreadsheets.*http://www.fao.org/fishery/topic/16077/en. October 14*, 2013

FAO (2013c) CLIMPROD - Experimental interactive software for choosing and fitting surplus production models including environmental variables. http://www.fao.org/fishery/topic/16070/en. October 14, 2013.

FAO (2013d) CLIMPROD-PLUS - Experimental interactive software for choosing and fitting surplus production models including environmental variables. http://www.fao.org/fishery/topic/16071/en. October 14, 2013.

FAO (2013e) FishStatJ - software for fishery statistical time series.http://www.fao.org/fishery/statistics/software/fishstatj/en. October 14, 2013.

FAO (2013f) FishStat Plus - Universal software for fishery statistical time serie. shttp://www.fao.org/fishery/statistics/software/fishstat/en . October 14, 2013.

FAO (2013g) SPATIAL - Space time Dynamics in Marine Fisheries. http://www.fao.org/fishery/topic/16076/en. October 14, 2013.

FAO (2013h) BEAM4 - Analytical Bioeconomic Simulation of Space structured Multispecies and Multifleets Fisheries. http://www.fao.org/fishery/topic/16069/en. October 14, 2013.

FAO (2013i) VONBIT 2005 - Von Bertalanffy Iterative Approach http://www.fao.org/fishery/topic/16078/en. October 14, 2013.

Garrison, L. P., Link, J. S., Kilduff, D. P., Cieri, M. D., Muffley, B., Vaughan, D. S., Sharov, A., Mahmoudi, B., and Latour, R. J. (2010) An expansion of the MSVPA approach for quantifying predator–prey interactions in exploited fish communities. – ICES Journal of Marine Science, 67: 856–870.

Gordon, H.S. (1953) An economic approach to the optimum utilization of fishery resources. *J. Fish. Res. Bd. Can.* 10: 442–447.

Gordon, H.S. (1954) The economics of a common property resource: the fishery. *J. Polit. Econ.* 62: 124–142

Herrnkind, W. F. 1980. “Spiny Lobsters: Patterns of Movement.” – *In:* The Biology and Management of Lobsters, Vo. I: Physiology and Behavior, pp 350-389. J.S. Cobb and B.F. Phillips, Eds. New York: Academic Press.

Hoggarth, D.D.; Abeyasekera, S.; Arthur, R.I.; Beddington, J.R.; Burn, R.W.; Halls, A.S.; Kirkwood, G.P.; McAllister, M.; Medley, P.; Mees, C.C.; Parkes, G.B.; Pilling, G.M.; Wakeford, R.C.; Welcomme, R.L. (2006) Stock assessment for fishery management – A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP).

ICES (2012) Report on the Classification of Stock Assessment Methods developed by SISAM. ICES CM 2012/ACOM/SCICOM:01. 15 pp.

Jones, R. (1984) Assessing the effects of changes in exploitation pattern using length composition data (with notes in VPA and cohort analysis). *FAO Fish. Tech. Pap.*, 256: 118 pp.

Lassen, H. & P. Medley (2001) Virtual Population Analysis. A practical manual for stock assessment. *FAO Fish.Tech.Pap*.400. 129 pp

MacCall, A. D. (2009) Depletion-corrected average catch: a simple formula for estimating sus-tainable yields in data-poor situations. ICES Journal of Marine Science, 66: 2267–2271.

OSPESCA (2012) MANEJO REGIONAL DE LA PESQUERIA DE LA LANGOSTA ESPINOSA DEL CARIBE (*Panulirus argus*).

Marx, J.M., Herrnkind, W.F., 1985. Macroalgae (Rhodophyta: Laurencia spp.) as habitat for young juveniles spiny lobster *Panulirus argus*. Bull. Mar. Sci.36, 423–431.

McCullagh, P., Nelder, J.A., (1989) Generalized Linear Models, 2nded. Chapman & Hall, London.

Pauly, D., V. Christensen & C. Walters (2000) Ecopath, Ecosim and Ecospace as tools for evaluating ecosystem impact of fisheries. *ICES J. Mar. Sci*., 57:697-706

Pope, J.G. & J.G. Shepherd (1982) A simple method for the consistent interpretation ofcatch-at-age data. *J. Cons. int. Explor. Mer*, 40:176-184

Pulliam, H. R. (1988) Sources, sinks, and population regulation. The American Naturalist 132: 653–661.

Rothschild, B.J., S.G. Smith and H. L. (1996) The application of time series analysis to fisheries population assessment and modeling. In: Gallucci, V.F., S.B. Saila, J.

Gustafson and B.J. Rothschild. (Eds,). *Stock Assessment: quantitative methods andapplications for small-scale fisheries.* CRC Press.Lewis Publishers. 527 pp. 354-402

Sanchirico, J.N., Wilen, J.E., (2001) Dynamics of spatial exploitation: A meta population approach., Natural Resource Modeling . 14 (3), pp 391-418.

Seijo, J.C. 2007. Considerations for management of metapopulations in small-scale fisheries of the Mesoamerican barrier reef ecosystem. Fisheries Research 87: 86–91.

Shepherd, J.G. (1988) Fish stock assessments and their data requirements. Pp 35-62 in Gulland, J.A. (Ed.), Fish Population Dynamics (Second Edition).John Wiley & Sons.

Shepherd, J.G. (1999) Extended survivors analysis: an improved method for the analysis of catch-at-age data and abundance indices. *ICES J. Mar. Sci*., 56:584-591.

Smith, V.L. (1969) On models of commercial fishing. *J. Polit. Econ.* 77: 181–198.

Sparre, P., Ursin, E. &Venema, S.C. (1989) Introduction to tropical fish stock assessment. Part 1.Manual.FAO Fish. Tech. Pap. 306.1. Rome, FAO. 337 pp.

Sparre, P. &Venema, S.C. (1998) Introduction to tropical fish stock assessment.Part 1.Manual (Rev. 2).FAO Fish. Tech. Pap. 306.1. Rome, FAO. 407 pp.

Sparre, P. (1991) Introduction to multispecies virtual population analysis *ICES Mar. Sci.Symp*., 193:12-21

Stamatopoulos, C. (2002) Sample-based fishery surveys: A technical handbook. FAO Fisheries Technical Paper, No. 425.FAO, Rome, Italy.132 pp.

Thompson, W.F. and F.H. Bell (1934) Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Rep. Int. Fish. (Pacific Halibut) Comm.,* 8:49 pp

Wilen, J., 2003. Spatial Management of Fisheries. Marine Resource Economics, 19(1):7-20.

Appendix 1: Questionnaire Circulated to Countries

1. ***Country Information***

Country	
Name of Organization/Institution	
Name of person completing questionnaire and designation	

2. ***Fishery Description***

a. In the table below, provide the best available information for the spiny lobster (*Panulirusargus*) fishery and references where possible.

Category			**References**
Fishers	Number		
Number of fishers (2012)			
Vessels	Number	Size range (m)	
Number of small-scale boats (2012)			
Number of semi-industrial boats (2012)			
Number of mother ships (2012)			
Number of industrial boats (2012)			
Landings	Quantity (t)		
Average landings (2002-2012)			
Average export (2002-2012)			

b. In the table below, indicate which of the following gears/methods are used in the spiny lobster fishery.

Gear/Method	Utilized (Yes/No)
Diving	
SCUBA	
Compressed air (Hookah)	
Free diving	
Lobster aggregating devices(casitas, drums, shades)	
Nets	
Gill nets	
Trammel nets	
Traps	

c. Provide a brief description below, if gears/methods other than those listed at 2. (b.) are used in the spiny lobster fishery.

d. In the table below indicate, which of the following criteria are used to classify boat/gear categories within the spiny lobster fishery.

Category	Utilized (Yes/No)
Spiny lobster size	
Catch rates	
Fishing trip patterns	
Fishing gear/method	
Boat size	

e. Provide a brief description below, if categories other than those listed at 2. (d.) are used to classify boat/gear categories within the spiny lobster fishery.

3. Data

a. In the table below, indicate the methods used to monitor and record spiny lobster catch and effort, the time periods for which they have been used and references where possible.

Method	Utilized for catch (Yes/No)	Time period	Utilized for effort (Yes/No)	Time period	References
Data collectors					
Market records					
Export records					
Observer programmes					
Logbooks					

b. Provide a brief description below, if methods other than those listed at 3. (a.) are used to monitor and record spiny lobster catch and effort, and indicate the time period for which they have been used and references where possible.

c. In the table below, indicate the types of data which are typically collected for the spiny lobster fishery, the time period (years) for which they are available and references where possible.

Category		Available (Yes/No)	Time period	References
Total catch estimated by:	Geographical area/stratum			
	Given reference period (e.g calendar month)			
	A specific boat/gear category			
Total effort estimated by:	Complete enumeration through census of spiny lobster fishing activities			
	Census in space and sampling in time			
	Sampling in space and census in time			
	Sampling in both space and time			
	A specific boat/gear category			
Biological	Total length			
	Carapace length			
	Whole weight			
	Tail weight			
	Age			
	Sex			
Ecological	Habitat information			
	Species interactions			
Economic	Investment costs per boat/gear category			
	Operational costs per boat/gear category			
	Size specific ex-vessel prices			
	Profits per boat/gear category			

d. Provide a brief description below, if data types other than those listed in 3.(c.) are typically collected for the spiny lobster fishery, and indicate the time period (years) for which they are available and references where possible.

4. Assessment Methods

a. In the table below, indicate which methods have been utilized to assess the spiny lobster fishery, indicate the year(s) in which they were completed and references where possible.

Method	**Completed (Yes/No)**	**Years**	**References**
Virtual population analysis			
Length cohort analysis			
Yield per recruit			
Stock-recruitment relationship			
Production model			
Bio-economic model			
Multispecies model			
Ecological model			
Time series analysis			
Generalized linear model			
Underwater survey			
Tagging programme			

b. Provide a brief description below, if methods other than those listed at 4. (a.) have been utilized to assess the spiny lobster fishery and indicate the year(s) in which they were completed and references where possible.

Appendix 2: Names and Designations of Questionnaire Respondents by Country

ANGUILLA

James C. Gumbs	Director Department of Fisheries and Marine Resources Ministry of Home Affairs, Environment, Agriculture, Fisheries, Lands Anguilla

ANTIGUA and BARBUDA

Ian Horsford,	Senior Fisheries Officer Fisheries Division Ministry of Agriculture, Lands, Housing and the Environment Antigua and Barbuda

THE BAHAMAS

Michael T. Braynen	Director Department of Marine Resources Ministry of Agriculture and Marine Resources The Bahamas
Lester Gittens	Assistant Fisheries Officer Department of Marine Resources Ministry of Agriculture and Marine Resources The Bahamas

BELIZE

Mauro Gongora	Fisheries Officer Fisheries Department Ministry of Forestry, Fisheries and Sustainable Development Belize

BERMUDA

Joanna Pitt	Researcher Marine Resources Section Department of Environmental Protection Bermuda

BRAZIL

Paulo Parente Lira Cavalcante	Technical Advisor Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - Ibama Centro Nacional de Informação Ambiental Brasília-DF

COLOMBIA

Vladimir Puentes Granada	Jefe Oficina de Generación del Conocimiento y la Informacion Autoridad Nacional de Acuicultura y Pesca AUNAP

Colombia

COSTA RICA

Juan Luis Córdoba Mora — Director Regional de INCOPESCA-
Oficina Instituto Costarricense de Pesca y Acuicultura
Costa Rica

CUBA

Rafael Tizol Correa — Director General de CIP-
Centro de Investigaciones Pesqueras
Cuba

DOMINICAN REPUBLIC

Jeannette Mateo — Directora Interina de la Dirección de
Recursos Pesqueros
Subsecretaría de Estado de Recursos
Costeros y Marinos
Republica Dominicana

GRENADA

Crafton Isaac — Fisheries Officer
Fisheries Division
Ministry of Agriculture, Forestry and Fisheries
Grenada

GUADELOUPE

Lionel Reynal — Researcher
French Research Institute for Exploration of the Sea
(IFREMER)
Martinique

Olivier Guyader — Researcher
French Research Institute for Exploration of the Sea
(IFREMER)
Martinique

GUATEMALA

Manoel Cifuentes — Asistente Técnico Nacional en Manejo
Subregional de las Pesquerias de Langota Espinosa del
Caribe (*Panulirus argus*) (MASPLESCA)
Dirección de la Normatividad de la Pesca y Acuicultura
(Dipesca), del Ministerio de Agricultura, Ganadería y
Alimentación (Maga)
Guatemala

HAITI

Jean Robert Badio — Director of Fisheries & Aquaculture
Ministry of Aquaculture and Natural Resources
Haiti

HONDURAS

Miguel Suazo — Jefe de Departamento Pesca artesanal

	La Dirección General de Pesca y Acuicultura-DIGEPESCA Honduras
JAMAICA	
Ricardo Morris	Fisheries Officer Fisheries Division Ministry of Agriculture and Fisheries Jamaica
MARTINIQUE	
Lionel Reynal	Researcher French Research Institute for Exploration of the Sea (IFREMER) Martinique
MEXICO	
José Guadalupe Trujillo Jiménez	Director General de Planeación, Programación y Evaluación de la CONAPESCA- Comisión Nacional de Acuacultura y Pesca México
Aldo Gerardo Padilla Pestaño	Director General de Ordenamiento Pesquero y Acuícola de la CONAPESCA
Raúl Adán Romo Trujillo	Director en Jefe del INAPESCA-Instituto Nacional de Pesca México
MONTSERRAT	
John Jeffers	Fisheries Officer Department of Fisheries Montserrat
NICARAGUA	
Danilo Pichardo Rosales	Viceministrode las Pesquerías Instituto Nicaragüense de la Pesca y la Acuicultura-INPESCA Nicaragua
PANAMA	
Anna Núñez Pereligina	Jefa de Investigación Autoridad de los Recursos Acuáticos de Panama-ARAP Panama
SABA	
Martin de Graaf	Research Scientist Institute for Marine Resources and Ecosystem Studies-IMARES The Netherlands
ST. EUSTATIUS	
Erik Bowman	Research Scientist Fisheries Department

	Caribbean Netherlands
Martin de Graaf	IMARES
ST. KITTS and NEVIS	
Samuel Heyliger	Assistant Fisheries Officer Department of Marine Resources Ministry of Marine Resources St. Kitts
ST. LUCIA	
Thomas Nelson	Fisheries Biologist Department of Fisheries Ministry of Agriculture, Food Production, Fisheries and Rural Development St. Lucia
Patricia Hubert-Medar	Fisheries Assistant Department of Fisheries Ministry of Agriculture, Food Production, Fisheries and Rural Development St. Lucia
ST. VINCENT AND THE GRENADINES	
Kris Isaacs	Fisheries Officer Fisheries Division Ministry of Agriculture, Rural Transformation, Forestry, Fisheries and Industry St. Vincent and the Grenadines
TRINIDAD AND TOBAGO	
Christine Chan A Shing	Director of Fisheries Fisheries Division The Ministry of Food Production Trinidad and Tobago
TURKS AND CAICOS ISLANDS	
Luc Clerveaux	Environmental Officer Department of Environment and Coastal Resources Ministry of Environment and District Administration Turks & Caicos Islands
USA	
Tom Matthews	Fisheries Biologist Florida Fish and Wildlife Conservation Commission. USA
VENEZUELA	
Dulce Nathalie Arocha Pérez	Researcher Instituto Socialista de la Pesca y Acuicultura - INSOPESCA Venezuela

Appendix 3: Questionnaire Responses Summarized by Country

Table 1: Fishery description-number of fishers and boat categories

Country	Number of fishers (2012)	Number of small-scale boats (2012)	Size range (m)	Number of semi-industrial boats (2012)	Size range (m)	Number of motherships (2012)	Size range (m)	Number of industrial boats (2012)	Size range (m)
Anguilla	103	45	3-16						
Antigua and Barbuda[13]		228 (2010)	3.4-17.7						
The Bahamas									
Belize	2582 (2011)	752 (2011)	8-12						
Bermuda	30	30	5-12						
Brazil	11000 (2008)	3704 (2008)	< 8 (413) 8- 12 (1350) > 12 (236)	54 (2008)	< 25 (48) > 25 (6)				
Colombia (San Andres y Providencia)	1283	160	4-8					32	15-25
Colombia (la Guajira)	900	700							
Costa Rica	500	125	7-9						
Cuba	1200			176	14-21				
Dominican Republic	1696	428	13-25	29					

[13] Data only available up to 2010. Data for 2011 and 2012 are being validated.

Country	Number of fishers (2012)	Number of small-scale boats (2012)	Size range (m)	Number of semi-industrial boats (2012)	Size range (m)	Number of motherships (2012)	Size range (m)	Number of industrial boats (2012)	Size range (m)
Grenada	216	72							
Guadeloupe	290 (2011)	156 (2011)	5-9						
Guatemala	309	70	6						
Haiti	4700	2830	5-8	2	10-20				
Honduras	3855	33	<7			3		122	20-21
Jamaica									>25
Martinique	661 (2011)	361 (2011)							
Mexico		865	7.32	11	12-18	22	12-18		
Nicaragua	1978 (910 artisanal; 1068 industrial)	257	15					65(47 traps; 18 divers)	>15m
Panama	800 (600-Bocas del Toro; 200-Comarca GunaYala)								
Saba	9	9	10-11						
St. Eustatius	15	8	5-8						
St. Kitts&Nevis	651	216	5-11						
St. Lucia	2556	700	2.7-22.9						
St. Vincent& the Grenadines	141	47	3-6						
Trinidad & Tobago									

Country	Number of fishers (2012)	Number of small-scale boats (2012)	Size range (m)	Number of semi-industrial boats (2012)	Size range (m)	Number of motherships (2012)	Size range (m)	Number of industrial boats (2012)	Size range (m)
Turks& Caicos Islands	264	83	5-7	7	10-15				
UnitedStates-Florida	764	450	5-10	350	7-22				
Venezuela	310	140	6-10						

Table 2: Landings and export data for spiny lobster

Country	Average landings (t) (2002-2012)	Average export (t) (2002-2012)
Anguilla	101.3	<10
Antigua and Barbuda	239 (2002-2010)	47 (2002-2010)
Bahamas	2948	2507
Belize	231 (tails)	218 (tails)
Bermuda	37.2	
Brazil[14]	6959.66 (2002-2011)	2173.60
Colombia (San Andres y Providencia)	1560	
Colombia (la Guajira)	45.4	

[14] Overall catches are composed of *Panulirus argus* (85%) and *P. laevicauda* (15%)

Costa Rica	31.7	
Cuba	4800	
DominicanRepublic[15]	1331	38.8 (2007-2011)
Grenada	25.6	3.8
Guadeloupe	98 (2011)	
Guatemala	1.7 (2012)	
Haiti		320
Honduras	816.47	6517.68
Jamaica		283
Martinique	49.6 (2011)	
Mexico	1060-whole weight; approximately 353-tail weight (2001-2011)	60% (2012)
Montserrat[16]	<0.25	
Nicaragua	3954-whole weight; 1318-tailweight	3186- whole weight; 1062-tailweight
Panama[17]		Exported lobster not differentiated by species or areas caught (Pacific or Atlantic)
Saba	100	100
St. Eustatius		
St. Kitts&Nevis	17	

[15] The average import of spiny lobster during 2010-2012 was 4046.8t.
[16] There is no targeted fishery for spiny lobster, it is caught in the multi-species fisheries and there are no data collection programmes for this species.
[17] Other species caught include *P. gracilis* (Pacific Coast) and *P. guttatus*

St. Lucia	15.9	
St. Vincent& The Grenadines	21	17
Trinidad & Tobago[18]	1.7 (2006-2010)	
Turks& Caicos Islands	319	91
United States-Florida	2000	
Venezuela	58 (Morro de Puerto Santo, Estado Sucre)	

Table 3: Fishing gear/method for spiny lobster

Country	Diving/SCUBA	Diving/Compressed air (Hookah)	Diving/Free diving	Lobster aggregating devices (casitas, drums, shades)	Nets/Gill nets	Nets/Trammel nets	Traps
Anguilla							X
Antigua & Barbuda	X		X				X
The Bahamas[19]		X	X	X			X
Belize			X	X			X
Bermuda[20]			X				X
Brazil		X	X	X	X		X
Colombia (San Andres y Providencia)			X	X			X
Colombia (la			X	X	X		X

[18] There is no targeted fishery for spiny lobster, it is caught in the multi-species fisheries. No systems have been established for monitoring the capture of this species in either Trinidad or Tobago.

[19] Spears powered by a non-triggered rubber sling are also used to capture spiny lobster

[20] Standardized traps are owned by the government and leased to licensed commercial fishers. There are 29 allottments of 12 traps each, with one shared allotment, for a total of 30 participants in the small-scale commercial fishery. Recreational lobster fishers free dive and use a noose to capture lobsters.

Country	Diving/SCUBA	Diving/Compressed air (Hookah)	Diving/Free diving	Lobster aggregating devices (casitas, drums, shades)	Nets/Gill nets	Nets/Trammel nets	Traps
Guajira)							
Costa Rica			X			X	X
Cuba[21]			X	X			X
DominicanRepublic[22]		X	X	X			X
Grenada	X		X			X	X
Guadeloupe			X		X	X	X
Guatemala		X				X	
Haiti	X	X	X	X	X		X
Honduras	X	X					X
Jamaica	X	X	X			X	X
Martinique			X		X	X	X
Mexico[23]		.X	X	X	X		X
Nicaragua	X	X	X				X
Panama			X	X			
Saba							X
St.Eustatius	X		X				X
St. Kitts&Nevis	X		X				X
St. Lucia			X		X		X
St. Vincent& the Grenadines	X		X	X			X
Trinidad & Tobago	X		X				X
Turks& Caicos Islands			X	X			X
UnitedStates-Florida[24]	X	X	X				X

[21] Small nets are used in combination with lobster aggregating devices.
[22] Small nets are also used to capture spiny lobster.
[23] Hooks with pointed curves are used to retrieve lobsters
[24] Approximately 480, 000 traps are used to capture 94% of the commercial spiny lobster catch. 250 licensed divers use primarily SCUBA to catch about 5% of the commercial spiny lobster catch. Approximately 25 fishers use hand held nets on a pole to catch spiny lobster.

Country	Diving/SCUBA	Diving/Compressed air (Hookah)	Diving/Free diving	Lobster aggregating devices (casitas, drums, shades)	Nets/Gill nets	Nets/Trammel nets	Traps
Venezuela	X		X				X

Table 4: Criteria used to define specific boat/gear categories in the spiny lobster fishery

Country	Spiny lobster size	Catch rates	Fishing trip patterns	Fishing gear/method	Boat size
Anguilla					
Antigua & Barbuda[25]			X	X	X
The Bahamas				X	
Belize				X	
Bermuda				X	
Brazil				X	X
Colombia (San Andres y Providencia)	X	X	X	X	X
Colombia (la Guajira)				X	X
Costa Rica				X	X
Cuba					
DominicanRepublic			X		X
Grenada				X	X
Guadeloupe				X	
Guatemala				X	X
Haiti					
Honduras	X		X	X	X
Jamaica				X	X
Martinique				X	
Mexico				X	X
Nicaragua	X		X	X	X
Panama					
Saba					
St. Eustatius				X	X
St. Kitts&Nevis				X	

[25]In the case of traps, a spiny lobster trip is identified by depth fished, bait used, and soak time

Country	Spiny lobster size	Catch rates	Fishing trip patterns	Fishing gear/method	Boat size
St. Lucia				X	
St. Vincent& the Grenadines					
Trinidad & Tobago					
Turks& Caicos Islands					X
UnitedStates-Florida				X	
Venezuela	X		X	X	

Table 5: Data collection methods for the spiny lobster fishery- catch

Country	Data collectors	Time period	Market records	Time period	Export records	Time period	Observer programmes	Time period	Logbooks	Time period
Anguilla	X	2009-present								
Antigua and Barbuda	X				X				X	
The Bahamas[26]	X	1987-2013	X	1988-2013	X	1988-2013				
Belize[27]	X	2000-2012			X	2000-2012			X	2000-2012
Bermuda							X	1996-present	X	1975-1990 (summary) 1991-present (detailed)
Brazil	X	1965-1990			X	1970-present			X	1970-present
Colombia (San Andres y Providencia)[28]	X	2005-2006			X	2010-2012			X	
Colombia (la Guajira)	X	2006-2012	X	2006-2012						
Costa Rica	X									
Cuba	X	2000-2012			X	2000-2012			X	
DominicanRepublic	X	2012-present			X	2008-	X	2008-	X	2008-present

[26]Catch certificates as required by the European Union Rules for export also provide catch and effort information and are available from 2010-2013.
[27] Logbook data are available for the Glovers Reef and Port Honduras Managed Access Programs.
[28] An observer program is currently being developed for implementation.

Country	Data collectors	Time period	Market records	Time period	Export records	Time period	Observer programmes	Time period	Logbooks	Time period
						present		present		
Grenada			X	>25 years						
Guadeloupe	X	2008;2010;2011								
Guatemala			X	2012						
Haiti					X					
Honduras	X				X				X	
Jamaica	X				X				X	
Martinique	X	2009-present								
Mexico	X	1990-2012							X	2000-2012
Nicaragua	X		X	2000-2012	X	2000-2012	X		X	
Panama	X									
Saba[29]	X	2000;Jul-Nov 2007;2012-present								
St. Eustatius	X	2012-present							X	2012-present
St. Kitts&Nevis	X	1984-1986; 1995-present	X	1984-1986						
St. Lucia	X	1981-2013								
St. Vincent& the Grenadines	X		X		X					
Trinidad & Tobago										
Turks& Caicos Islands	X	1947-present	X	1957-present	X		X		X	1947-present
UnitedStates-Florida	X	1986-present	X		X		X	1993-2000; 1986-present		

Table 6: Data collection methods for the spiny lobster fishery- effort

[29] In the Caribbean Netherlands (Saba and St.Eustatius), a port sampling programme has been in place consisting of the following components: (i) daily trip logs; (ii) a short interview which captures 20% of the fishing trips; data on catch, effort (number of traps pulled), fishing area; and (iii) a long interview which captures 5% of the trips; measures the catch; species composition and length frequency.

Country	Data collectors	Time period	Market records	Time period	Export records	Time period	Observer programmes	Time period	Logbooks	Time period
Anguilla										
Antigua and Barbuda	X	NA							X	NA
The Bahamas	X	1987-2013								
Belize[30]	X	2000-2012			X	2000-2012			X	2000-2012
Bermuda									X	1975-1990;1991-present
Brazil	X	1965-1990							X	1970-present
Colombia (San Andres y Providencia)	X	2005-2006							X	
Colombia (la Guajira)	X	2006-2012	X	2006-2012						
Costa Rica	X									
Cuba	X	2000-2012			X	2000-2012			X	
DominicanRepublic	X	2012-present			X	2008-present	X	2008-present	X	2008-present
Grenada										
Guadeloupe	X	2008;2010;2011								
Guatemala			X	2012						
Haiti										
Honduras										
Jamaica	X				X				X	
Martinique	X	2009-present								
Mexico	X	2000-2012							X	2000-2012
Nicaragua										

[30] Fishing effort is estimated as the number of fishing trips. The total number of annual licensed fishers is multiplied by 2.5 and 8 with the assumption being that each fisher carries out an average of 2-5 trips per month during the 8 month fishing season.

Country	Data collectors	Time period	Market records	Time period	Export records	Time period	Observer programmes	Time period	Logbooks	Time period
Panama										
Saba	X	2000;Jul-Nov 2007;2012-present								
St. Eustatius	X	2012-present							X	2012-present
St. Kitts&Nevis	X									
St. Lucia	X	1978-2013								
St. Vincent& the Grenadines	X									
Trinidad & Tobago										
Turks& Caicos Islands	X	1965-present							X	1965-present
UnitedStates-Florida	X	1986-current					X			
Venezuela	X	2007-2008								

Table 7: Survey standards used for total catch estimation

Country	Geographical area/stratum	Time period	Given reference period (e.g.calendar month)	Time period	Specific boat/gear category	Time period
Anguilla						
Antigua and Barbuda	X		X		X	NA
The Bahamas						
Belize			X	2000-2012		
Bermuda	X	1975-	X	1975-1990	X	1975-present

Country	Geographical area/stratum	Time period	Given reference period (e.g.calendar month)	Time period	Specific boat/gear category	Time period
		present		1991-present		1996-present
Brazil	X		X	1991-2011		
Colombia (San Andres y Providencia)	X					
Colombia (la Guajira)	X	2006-2012	X			
Costa Rica						
Cuba	X	2000-2012	X	2000-2012		
DominicanRepublic	X		X		X	
Grenada	X	1978-present	X	1978-present	X	1978-present
Guadeloupe	X	2008, 2010, 2011	X			
Guatemala	X	2012	X	2012	X	2012
Haiti						
Honduras	X	2012			X	2012
Jamaica	X		X			
Martinique	X	2009-	X	2009-		
Mexico	X	1995-2011	X	1995-2011		
Nicaragua	X	1990-2012	X	1990-2012		
Panama						
Saba	X	2000; Jul-Nov 2007;2012-present	X	2000; Jul-Nov 2007;2012-present	X	2000; Jul-Nov 2007;2012-present
St. Eustatius	X	2012-present	X	2012-present	X	2012-present
St. Kitts&Nevis			X		X	
St.Lucia	X	1995-2013	X	1995-2013	X	1995-2013
St. Vincent& the Grenadines			X	1990-2012		
Trinidad & Tobago						
Turks& Caicos Islands	X	2004-present	X	1989-present	X	

Country	Geographical area/stratum	Time period	Given reference period (e.g.calendar month)	Time period	Specific boat/gear category	Time period
UnitedStates-Florida[31]	X	1986-current	X		X	
Venezuela	X	2007-2008	X	1996-2011		

Table 8: Survey standards used for total effort estimation

Country	Complete enumeration through census of spiny lobster fishing activities	Time period	Census in space and sampling in time	Time period	Sampling in space and census in time	Time period	Sampling in both space and time	Time period	A specific boat/gear category	Time period
Anguilla							X			
Antigua & Barbuda			X						X	
The Bahamas										
Belize										
Bermuda	X	1975-present 1996-present							X	1975-present 1996-present
Brazil	X	1965-	X		X	1974-1991	X	1974-1991		
Colombia (San Andres y Providencia)			X	2008-2009	X	2008-2009	X	2008-2009		
Colombia (la Guajira)							X	2006-20012	X	2006-2012
Costa Rica							X	2012		
Cuba[32]	X	2000-2012					X	2000-2012		
Dominican Republic			X		X				X	2000
Grenada										
Guadeloupe							X			
Guatemala									X	2012

[31] Florida requires a record of each commercial fishing trip which includes: date; gear; catch; and price.
[32] Fishing effort is calculated as numbers of days at sea.

Country	**Complete enumeration through census of spiny lobster fishing activities**	**Time period**	**Census in space and sampling in time**	**Time period**	**Sampling in space and census in time**	**Time period**	**Sampling in both space and time**	**Time period**	**A specific boat/gear category**	**Time period**
Haiti										
Honduras										
Jamaica									X	
Martinique							X			
Mexico	X	2012	X	2012						
Nicaragua	X	2007							X	2007
Panama										
Saba							X	2000, Jul-Nov 2007;2012-present		
St. Eustatius							X	2012-present		
St. Kitts&Nevis										
St. Lucia							X	1995-2013	X	1995-2013
St. Vincent& the Grenadines							X	1990-2012		
Trinidad & Tobago										
Turks& Caicos Islands	X	1989-present								
UnitedStates-Florida	X		X		X		X		X	
Venezuela										

Table 9: Biological data available for the spiny lobster fishery

Country	Total Length	Time period	Carapace Length	Time period	Whole Weight	Time period	Tail Weight	Time period	Age	Time period	Sex	Time period
Anguilla												
Antigua & Barbuda			X								X	
The Bahamas[33]							X	2005-2013			X	2005-2013
Belize			X	2011-2012			X	2000-2012	X	2000-2012	X	2011-2012
Bermuda			X	1996-present	X	1996-present					X	1996-present
Brazil												
Colombia (San Andres Y Providencia)	X	2008-2009	X	2008-2009	X	2008-2009	X	2008-2009	X	2008-2009	X	2008-2009
Colombia (la Guajira)	X	2007-2013	X	2007-2013	X						X	
Costa Rica			X	2012	X	2012					X	2012
Cuba			X		X				X		X	
DominicanRepublic												
Grenada					X	1978-present						
Guadeloupe			X		X							
Guatemala	X	2012	X	2012	X	2012	X	2012			X	2012
Haiti												
Honduras	X		X								X	
Jamaica			X								X	
Martinique			X		X							
Mexico					X	2001-2012					X	1990-2010
Nicaragua	X	2004-2012	X	2004-2012	X	2004-2012	X	2004-2012			X	2000-2012
Panama	X		X		X		X				X	

[33] Tail length frequency data are available from 2005-2012, and size classes of exported tails, by weight category are available form 1987-2012.

Country	Total Length	Time period	Carapace Length	Time period	Whole Weight	Time period	Tail Weight	Time period	Age	Time period	Sex	Time period
Saba[34]			X	2000, Jul-Nov 2007;2012-present							X	2000, Jul-Nov 2007;2012-present
St. Eustatius			X	2012-present							X	2012-present
St. Kitts&Nevis			X								X	
St. Lucia											X	1995-2013
St. Vincent& the Grenadines												
Trinidad & Tobago												
Turks& Caicos Islands[35]			X	2004-present	X	2004-present	X				X	2004-present
UnitedStates-Florida			X						X	2001	X	
Venezuela			X	2007-2008					X	2007-2008	X	2007-2008

Table 10: Ecological data available for the spiny lobster fishery

Country	Habitat Information	Time Period	Species Interactions	Time Period
Anguilla	X	2007-2012		
Antigua & Barbuda	X			
The Bahamas				
Belize				
Bermuda				
Brazil				
Colombia (San Andres y Providencia)	X	2008-2009		

[34] Collection of size at maturity commenced in 2012 along with a pilot study on recruitment index.
[35] On-going study in which small casitas are used to monitor recruitment of spiny lobster; and maturity data are also available.

Country	Habitat Information	Time Period	Species Interactions	Time Period
Colombia (la Guajira)	X	2007-2012		
Costa Rica				
Cuba	X	2000-2012		
DominicanRepublic				
Grenada				
Guadeloupe				
Guatemala	X	2012	X	2012
Haiti				
Honduras	X			
Jamaica				
Martinique				
Mexico	X	1997-2001;2010;2011;2012		
Nicaragua				
Panama				
Saba				
St. Eustatius				
St. Kitts&Nevis				
St. Lucia				
St. Vincent& the Grenadines				
Trinidad & Tobago				
Turks& Caicos Islands				
UnitedStates-Florida	X		X	
Venezuela				

Table 11: Economic data available for the spiny lobster fishery

Country	Investment costs per boat/gear category	Time period	Operational costs per boat/gear category	Time period	Size specific ex-vessel prices	Time period	Profits per boat/gear category	Time period
Anguilla								
Antigua & Barbuda	X		X				X	
The Bahamas								
Belize								
Bermuda[36]	X	1996-present			X			
Brazil								
Colombia (San Andres Y Providencia)								
Colombia (la Guajira)	X	2006-20012	X	2006-20012	X	2006-20012	X	2006-20012
Costa Rica								
Cuba								
Dominican Republic			X		X		X	

[36] Anecdotal information is available on the ex-vessel price of spiny lobster.

Country	Investment costs per boat/gear category	Time period	Operational costs per boat/gear category	Time period	Size specific ex-vessel prices	Time period	Profits per boat/gear category	Time period
Grenada								
Guadeloupe[37]	X		X		X		X	
Guatemala	X	2012	X	2012	X	2012	X	2012
Haiti								
Honduras	X		X		X		X	
Jamaica	X		X		X		X	
Martinique	X	Ongoing validation	X	Ongoing validation	X	Ongoing validation	X	Ongoing validation
Mexico					X	1990-2010		
Nicaragua	X	2007	X	2007	X	2007	X	2007
Panama								
Saba								
St. Eustatius								
St. Kitts&Nevis								
St. Lucia					X	1995-2013		
St. Vincent& the Grenadines								
Trinidad & Tobago								
Turks& Caicos								

[37] Economic data are currently being validated.

Country	Investment costs per boat/gear category	Time period	Operational costs per boat/gear category	Time period	Size specific ex-vessel prices	Time period	Profits per boat/gear category	Time period
Islands								
United States-Florida[38]	X		X					
Venezuela								

Table 12 a: Methods used to assess the spiny lobster fishery

Country	Virtual population analysis	Length cohort analysis	Yield/ recruit	Stock-recruitment relationship	Production model	Time series analysis	Generalized linear model
Anguilla							
Antigua & Barbuda		X			X	X	X
The Bahamas	X	X			X		
Belize[39]	X	X	X	X			
Bermuda		X			X	X	
Brazil[40]		X	X			X	X
Colombia (San Andres y Providencia)	X	X	X	X	X		
Colombia (la Guajira)							
Costa Rica							

[38] Economic studies are conducted on an *ad hoc* basis

[39] Assessments were conducted using data from 2000-2010.

[40] LCA & Y/R were conducted using data from 2000-2009; time series analysis was conducted using data from 1965-1990; and a generalized linear model was done using data from 1974-1991.

Country	Virtual population analysis	Length cohort analysis	Yield/ recruit	Stock-recruitment relationship	Production model	Time series analysis	Generalized linear model
Cuba[41]	X	X		X			
DominicanRepublic							
Grenada							
Guadeloupe							
Guatemala							
Haiti							
Honduras							
Jamaica[42]		X			X		
Martinique			X				
Mexico[43]	X	X		X	X		
Nicaragua	X	X	X	X			
Panama							
Saba							
St. Eustatius							
St. Kitts&Nevis							
St. Lucia							
St. Vincent & the Grenadines							
Trinidad & Tobago							
Turks& Caicos				X		X	

[41] Assessment methods were conducted using data from 2000-2012.
[42] LCA and a production model were completed using data from 1997-2007.
[43] VPA & LCA were conducted using data from 1987-1995; a stock recruitment relationship was conducted using data from 1987-2000; and a production model was completed using data from 1987-1995.

Country	Virtual population analysis	Length cohort analysis	Yield/ recruit	Stock-recruitment relationship	Production model	Time series analysis	Generalized linear model
Islands							
United States-Florida	X	X				X	
Venezuela[44]		X					

Table 12b: Methods used to assess the spiny lobster fishery

Country	Bio-economic models	Multispecies models	Ecological models	Underwater Survey	Tagging
Anguilla					
Antigua & Barbuda	X			X	X
The Bahamas					
Belize					
Bermuda					X
Brazil					
Colombia (San Andres y Providencia)	X	X	X		
Colombia (la Guajira)[45]				X	
Costa Rica					
Cuba	X				
Dominican Republic					

[44] LCA has been conducted using data from 2007-2008.
[45]Underwater surveys have been used from 2006-2012.

Country	Bio-economic models	Multispecies models	Ecological models	Underwater Survey	Tagging
Grenada					
Guadeloupe					
Guatemala				X	
Haiti					
Honduras					
Jamaica[46]	X				
Martinique					
Mexico[47]				X	
Nicaragua					
Panama		X			
Saba					
St. Eustatius					
St. Kitts&Nevis[48]					X
St. Lucia					
St. Vincent& the Grenadines					
Trinidad & Tobago					
Turks& Caicos Islands					
UnitedStates-Florida	X			X	X
Venezuela					

[46]The bioeconomic model was completed using data from 1997-2007.
[47]Underwater surveys were conducted during 1997-2001. In addition to these assessment methods, an age-structured model was completed using data from 1987-2011, and a delay difference model was completed using data from 1987-1995.
[48]A tag-recapture study was completed in 1986

Appendix 4: List of Available Documents Related to the Spiny Lobster Resource and Fishery by Country

Country	References
Antigua & Barbuda	Antigua & Barbuda Fisheries Act 2006
	Antigua & Barbuda The Fisheries Regulations, 2013, Statutory Instrument 2013, No.2
	Bannerot, S.P., Rhyther, J.H., Clark, M. Large-scale assessment of recruitment of post larval spiny lobsters, *Panulirus argus*, to Antigua, West Indies. Proceedings of the 41st GCFI.
	Harper, D. E. 1995. The 1995 spiny lobster update of the trends in landings, CPUE, and size of harvested lobster
	Horsford, I. 2012. Status of the Caribbean Spiny Lobster in 2010. A Presentation.
	Peacock, N. 1973. A study of the spiny lobster fishery of Antigua & Barbuda
	Tietze, U.; Thiele, W.; Lasch, R.; Thomsen, B; Rihan, D. Economic performance and fishing efficiency of marine capture fisheries. FAO Fisheries Technical Paper. No. 482. Rome, FAO. 2005. 68p.
The Bahamas	CRFM 2005. Report of the First Annual CRFM Scientific Meeting. CRFM Fishery Report No. 11. 318p.
	CRFM 2006. Report of Second Annual Scientific Meeting – Port of Spain, Trinidad and Tobago, 13-22 March 2006. CRFM Fishery Report - 2006, Volume 1.188 p.
	CRFM. 2007. CRFM Fishery Report-2007. Volume 1. Report of the Third Annual Scientific Meeting-St. Vincent and the Grenadines, 17-26 July 2007. 183 pp.
	CRFM.2008. CRFM Fishery Report-2008. Volume 1. Report of the Fourth Annual Scientific Meeting-Kingstown, St. Vincent and the Grenadines, 10-20 June 2008. 219 p.
	CRFM. 2009. CRFM Fishery Report-Volume 1. Report of the Fifth Annual Scientific Meeting-Kingstown, St. Vincent and the Grenadines, 09-18 June 2009. 167p.
	Medley, P. and Gittens, L. 2012. Bahamas Spiny Lobster Assessment In prep.
	Muller, R. and Puga, R. 2012. Bahamian spiny lobster stock assessment review
Belize	Belize Capture Fisheries Unit (CFU) Annual Report 2011
	Gongora, M. 2010. Assessment of the Spiny lobster (*Panulirus argus*) of Belize based on fishery –dependent data. The United Nations University Fisheries Training Program. Marine Fisheries Institute, Iceland.
	Glovers Reef and Port Honduras Marine Reserves Managed Access Program reports
Bermuda	FAO. 2001 .Report on the FAO/DANIDA/CFRAMP/WECAFC Regional Workshops on the Assessment of the Caribbean Spiny Lobster (*Panulirus argus*). Belize City, Belize, 21 April-2 May 1997 and Merida, Yucatan, Mexico, 1-12 June 1998. FAO Fisheries Report. No. 619. Rome. 381p
	FAO. 2003. Report of the second Workshop on the Management of Caribbean Spiny Lobster Fisheries in the WECAFC Area. Havana, Cuba, 30 September – 4 October 2002. FAO Fisheries Report No. 715. Rome 273 p.
	Government of Bermuda (2012) Summary of the spiny lobster fishery for the 2011-2012 season
	Luckhurst, B. Trott, T. Simmons, N. and Manual, S., (2002) Movement patterns of tagged spiny lobsters *Panulirus argus* on the Bermuda Reef Platform. 53rd GCFI Proceedings: 76-82
Brazil	Plano de gestão para o uso sustentável de Lagostas no Brasil:*Panulirus argus* (Latreille, 1804) e *Panulirus laevicauda* (Latreille, 1817)/José Dias Neto, Organizador. – Brasília: Ibama, 2008.

Country	References
	Cruz, R. and Borda, C. A. 2013. Estimation of abundance and spatial distribution of *Panulirus argus* using different methodologies in artificial shelter, trap and coral reef fisheries. Crustaceana 86 (2): 158-181
Colombia (San Andres y Providencia)	Borda, C. and Cruz, R. 2007. Evaluación de la Pesqueria de Langosta (*Panulirus argus*) en el Archipiélago de San Andres, Providencia Y Santa Catalina, Caribe Colombiano
	Informe Del Comité Técnico Interinstitucional, Propuesta de Cuotas Globales de Pesca - AUNAP - Autoridad Nacional de Acuicultura y Pesca, Ministerio de Agricultura y Desarrollo Rural Dirección de Pesca y Acuicultura, 2012.
	Suarez, A. 2009. Informe- Base de Datos, Situación de Las Flota Marine de la Pesca Comercial en Colombia Presentado a La Subgerencia de Pesca y Acuicultura del ICA
	Universidad Distrital- Tesis de grado, 2012.Evaluación Ambiental Integral de la Pesquería de Langosta Espinosa en el Archipiélago de San Andres y Providencia.
	Informes VUCE – AUNAP, 2012
Colombia (la Guajira)	Amezquita, M., De la Hoz, J y L. Whisgman. 1999. Experimentación y validación técnico económica de refugios artificiales para la pesca de la langosta *Palinurus argus* (Latreille, 1804) en la costa de la Guajira. Memoria de grado como requisito parcial para optar al título de Ingeniero Pesquero. Universidad del Magdalena, Facultad de Ingeniería, Programa de Ingeniería Pesquera, Santa Marta D. T.C.H., 151p.
	Barreto, C y Borda, C. 2008. Evaluación de Recursos Pesqueros Colombianos. Ministerio de Agricultura y Desarrollo Rural. Instituto Colombiano Agropecuario, ICA, Subgerencia de Pesca y Acuicultura. Bogotá. 131 p.
	Barreto, C., Borda, C., Otto, J., Sanchez, C., Sanabria, A., Puentes, V. y Muñoz, S. 2009. Propuesta de Cuotas Globales de Pesca y otras Medidas de Manejo para el aprovechamiento de los Recursos Pesqueros Colombianos. Vigencia 2010. Instituto Colombiano Agropecuario ICA. 113 p.
	Porras Díaz, D C. 2010.Aporte al conocimiento de algunos aspectos poblacionales y de la pesquería de la langosta espinosa *Palinurus argus* (Latreille, 1804) y de la Cangreja *Mithrax spinosissimus* (Latreille, 1818) capturadas en el Parque Nacional Natural Corales del Rosario y de San Bernardo, sector Archipiélago de San Bernardo, Caribe Colombiano. Tesis de grado para optar por el título de Bióloga Marina. Universidad de Bogotá Jorge Tadeo Lozano, Facultad de Ciencias Naturales e Ingeniería. Programa de Biología Marina.
	Nieto, S. 2007. Parámetros poblacionales y evaluación de la pesquería de langosta espinosa *Palinurus argus,* en la media Guajira, Caribe colombiano. Trabajo de grado presentado como requisito parcial para optar por el título de Biólogo Marino, Fundación Universidad de Bogotá Jorge Tadeo Lozano, Facultad de Biología Marina. Bogotá. 85 p.
	Ecosfera-Foro pesquero 2008-2012. Datos e información anual en el desarrollo de sistemas sostenibles de producción pesquera. 2da Semana Nacional de la Ciencia la Tecnología y la Innovación. Riohacha, pp 224.
	AUNAP-ECOSFERA. 2012. Evaluación biológico pesquera y socioeconómica de la Langosta espinosa en el departamento de la Guajira. Convenio 014.
Cuba	Puga, R., R. Pineiro, R. Alzugaray, L. S. Cobas, M. Estela de Leon, and O. Morales. 2013. Integrating Anthropogenic and Climatic Factors in the Assessment of the Caribbean Spiny Lobster (*Panulirus argus*) in Cuba: Implications for Fishery Management. International Journal of Marine Science 2013, Vol.3, No.6, 36-45
Guatemala	INFORME FINAL DE CONSULTORIA MASPLESCA/OSPECA/GUATEMALA

Country	References
	Dirección de Normatividad de la Pesca y Acuicultura Veda de langosta 2012
Jamaica	Morris, R. 2011. A Bio-economic Analysis of the Jamaican Industrial Spiny Lobster Fishery (*Panulirus argus*) The United Nations University Fisheries Training Program. Marine Fisheries Institute, Iceland.
Martinique	Gobert, 1989
Mexico	Diario Oficial de la Federación. CNP. 2012. Segunda Sección. Viernes 24 de agosto de 2012.
	Ríos-Lara G. V., J. C. Espinoza-Méndez., C. Zetina-Moguel., C. Aguilar-Cardozo y A. Ramírez-Estévez. 2013. La Pesquería de langosta *Panulirus argus* en el Golfo de México y mar Caribe mexicano. Libro de divulgación. INAPESCA. SAGARPA. 120 p.
	Subdelegaciones de Pesca en los estados de Quintana Roo y Yucatán
	José Luis Carrillo Galaz. Federación de Sociedades Cooperativas del Centro-Poniente de Yucatán. 2013. Com. Per.
	Sociedades Cooperativas de Producción Pesquera.
	Ríos-Lara G. V. y I. Peniche-Ayora. 2011. Análisis de la estructura de la población de langosta *Panulirus argus* capturada en la plataforma de Yucatán (1987-2010).
	Reuniones Nacionales de Investigación e Innovación Agroalimentaria y Forestal en México. II Reunión Nacional de Innovación Pesquera y Acuícola. León, Gto. Octubre, 2011. 14 p.
	AEAP (2001-2012)
	Bello P. J., G. V. Ríos Lara., M. A. Liceaga C., C. Zetina M., K Cervera., P. Arceo y H. Hernández. 2005. Incorporating spatial análisis of habitat into lobster (*P. argus*) stock assessment at Alacranes ref., Yucatan ,Mexico. Fish. Res. 73:37-47 p.
	Ríos-Lara G. V., S. Salas, J. Bello-Pineda e I. Peniche-Ayora. 2007. Distribution patterns of spiny lobster (*Panulirus argus*) at Alacrán Reef, Yucatán: Spatial analysis y inference of preferential habitat. Evaluation y Management Coast Fisheries in Latin America y Caribbean.*Special Issue*. *Fisheries Research*. 87: 35-45.
	Ríos-Lara G. V., C.E. Zetina-Moguel, I. Sánchez-Molina, J.I. Peniche-Ayora, R. Medina-González, J.C. Espinoza-Méndez y R. Moreno-Mendoza. 2011. Identificación y caracterización del hábitat de juveniles de langosta *Panulirus argus* en la costa central (Dzilam de Bravo) del estado de Yucatán, México. *Proceedings of the Gulf and Caribbean Fisheries Institute*. 63:462-470.
	Zetina-Ríos K. E., G. V. Ríos-Lara, R. Moreno-Mendoza, J.C. Espinoza-Méndez y C. Zetina-Moguel. 2012. Riqueza específica de peces en caladeros de pesca de langosta espinosa *Panulirus argus* en la costa central de Yucatán, México. *Proceedings of the Gulf and Caribbean Fisheries Institute*. 64: 468-471. P.
	Salas Márquez S., G. V. Ríos Lara., A. M. Arce Ibarra., I. Velázquez Abunader., M. A. Cabrera Vázquez., M. F. Cepeda González., D. Quijano Quiñones., R. Osvaldo Huchim Lara., J. Acosta Cetina., K. D. Infante Ramírez y A.U. Perez Cobb. 2012. Integración y asistencia para la concertación del Programa de Ordenamiento de la Pesquería de langosta en la península de Yucatán. CONAPESCA-INAPESCA-CINVESTAV-ECOSUR. 259 p.
	Zetina-Moguel, C., G.V. Ríos-Lara. 1998 Estimación del tamaño de la población, tasa de explotación y mortalidad por pesca de langosta *Panulirus argus* en las costas de Yucatán a través de diferentes modelos de evaluación. Proceedings of the 50TH Annual Gulf and Caribbean Fisheries Institute. 162-175.
	Sosa-Cordero E., A Ramírez-González y M Domínguez-Viveros. 1996. Evaluación de

Country	References
	la pesquería de langosta (*Panulirus argus*) de Banco Chinchorro, Quintana Roo. México, con base en el análisis de frecuencias de tallas. Proceedings of the Gulf y Caribbean Fisheries Institut 44: 103-120.
	Ríos Lara G. V., C. E. Zetina Moguel y P. Arceo Briseño. 2000 Evaluación de la población de langosta de las costas de Yucatán y análisis del efecto de la reducción de la talla mínima sobre la biomasa y la captura. Contribuciones de Investigación Pesquera. CRIPY. INP. SEMARNAP. Documento Técnico (8). 16-26 p. Agosto 2000.
	González-Cano J., F. Márquez-Farias y A. Ramírez-Estévez. 2001. Evaluación preliminar de la fracción de la población de langosta que se captura en aguas someras de Banco Chinchorro, Q. Roo. Informe Técnico (documento interno) Instituto Nacional de la Pesca CRIP Puerto Morelos, Quintana Roo. México. 39 p.
	Arce M., A. Clemetson., M. E. De León., Jaime González Cano., S. Marshalleck, S. O Brian, R. Puga., V. Restrepo., G. Richards., V. Ríos-Lara., E. Sosa and C. Zetina. 2001. Lobster Assessment Reports: Región 2: Belize, Southwest Cuba and México. Report on the FAO/DANIDA/CFRAMP/WECAFC REGIONAL WOKSHOPS ON THE ASSESSMENT OF THE CARIBBEAN SPINY LOBSTER (PANULIRUS ARGUS). FAO FISHERIES Report No, 619: 52-73.
	Ríos-Lara G.V., C. Zetina-Moguel, A. Ramírez-Estévez y C. Aguilar-Cardozo. 2012. Evaluación de los stock de langosta (*Panulirusargus*) en diferentes zonas de pesca de la costa de Yucatán y Quintana Roo, México. *Proceedings of the Gulf and CaribbeanFisheries Institute*.64:442-448 p.
	Zetina-Moguel, C., G.V. Ríos-Lara. 1998 Estimación del tamaño de la población, tasa de explotación y mortalidad por pesca de langosta *Panulirusargus* en las costas de Yucatán a través de diferentes modelos de evaluación. Proceedings of the 50^{TH} Annual Gulf and Caribbean Fisheries Institute. 162-175.
	Ríos-Lara G. V. y S. Salas. 2009. Modelo estructurado por edades para la evaluación de la población de langosta *P. argus* de la plataforma de Yucatán, México. Proceedings of the Gulf and CaribbeanFisheriesInstitute. 61: 451-460 p.
	Ríos Lara G. V. , K. Cervera Cervera., J.C. Espinoza Méndez., M. Pérez Pérez., C. Zetina Moguel y F. ChableEk. 1998. Estimación de las densidades de langosta espinosa (*Panulirusargus*) y caracol rosado (*Strombus gigas*) en el área central del arrecife Alacranes, Yucatán México. Proceedings of the 50^{TH} Annual Gulf and Caribbean Fisheries Institute. 104-127 p.
	Ríos Lara G. V.J. Bello Pineda., C. Zetina Moguel., K. Cervera Cervera Y P. Arceo Briseño. 2003. Estimación de Densidad Abundancia y Biomasa de la langosta espinosa *P. argus* en el Arrecife Alacranes en los Años 1997-1999 con Aplicación de GIS. Proceedings of the Gulf and Caribbean Fisheries Institute. 54: 272-284 p.
	Bello P. J., G. V. Ríos Lara., M. A. Liceaga C., C. Zetina M., K Cervera., P. Arceo y H. Hernández. 2005. Incorporating spatial análisis of habitat into lobster (*P. argus*) stock assessment at Alacranes ref.., Yucatan, Mexico. Fish. Res. 73:37-47 p.
	Ríos-Lara G. V., S. Salas, J. Bello-Pineda e I. Peniche-Ayora. 2007. Distribution patterns of spiny lobster (*Panulirus argus*) at Alacrán Reef, Yucatán: Spatial analysis by inference of preferential habitat. Evaluation y Management Coast Fisheries in Latin America y Caribbean.*Special Issue*. *Fisheries Research*. 87: 35-45.
	Ríos-Lara. 2009. Identificación del hábitat y de los factores que determinan la distribución espacial de langosta en la Plataforma de Yucatán: Modelación y evaluación de la población. Tesis de Doctorado. CINVESTAV-IPN, Unidad Mérida. México 155p.
Nicaragua	Encuesta estructural 2009 y base de datos de INPESCA 2012.

Country	References
	Informe de la cuantificación rápida del esfuerzo pesquero artesanal que se aplica al recurso langosta *Panulirus argus* del caribe de Nicaragua. Proyecto MASPLESCA – Agosto 2012.
	Anuario Pesquero y Acuícola de Nicaragua 2011 y base de datos estadísticas de INPESCA 2012.
	Informes técnicos del CIPA – INPESCA.
	Guía indicativa 2007, Boletines estadísticos pesqueros INPESCA 2000 - 2011 y Estadísticas pesqueras de INPESCA 2012.
	Boletines estadísticos pesqueros INPESCA 2000 -2011 y Estadísticas pesqueras de INPESCA 2012.
	Encuesta estructural 2007
	Informes Técnicos CIPA – INPESCA y Evaluación del estado de explotación de la langosta del Caribe de Nicaragua
	Informes Técnicos CIPA años 2000 - 2012
	Informe económico de las pesquerías de langosta y camarón del Caribe. Cesar Rivera 2007
	Informe final del estado del recurso "langosta espinosa" (*Panulirus argus*). Proyecto FIINPESCA-FAO, Dr. Renato Guevara
	Informe Técnico sobre el Cálculo de la cuota biológicamente aceptable (CBA) de la langosta Panulirus argus del caribe nicaragüense para el año bilógico (julio 2011 – febrero 2012). RenaldiBarnutty.-Marzo 2011.
Panama	Guzmán, Héctor M., Tewfik, Alexander, "Population characteristics and co-occurrence of three exploited decapods (Panulirus argus, P. guttatus, Mithrax spinosissimus) in Bocas del Toro, Panama", Journal of Shellfish Research, vol. 23, pp. 575-580, 2004.
	Arcadio Castillo and HA Lessios. 1998. Lobster Fishery By The Kuna Indians In The Region Of Panama San Blas (Kuna Yala)
Saba	Dilrosun, F. 2000. Monitoring the Saba Bank fishery. Department of Public Health and Environmental Hygiene, Environmental Division. Curaçao, Netherlands Antilles.
	Toller, W., Lundvall, S., 2008. Assessment of the commercial fishery of Saba Bank. Saba Conservation Foundation, 47pp.
US	Acosta, C.A., Matthews, T.R., Butler IV, M.J. 1997.Temporal patterns and transport processes in recruitment of spiny lobster (*Panulirus argus*) post larvae to South Florida. Marine Biology 129:79-85
	Cox C, Hunt JH, Lyons WG, Davis G (1997) Nocturnal foraging of the Caribbean spiny lobster (*Panulirus argus*) on offshore reefs of Florida, USA Mar Fresh Res 48: 671-679
	Cox C, Hunt JH (2005) Change in size and abundance of Caribbean spiny lobster *Panulirus argus* in a marine reserve in the Florida Keys National Marine Sanctuary, USA. Mar. Ecol.Prog.Ser. 294: 227-239
	Butler, M.J. IV. 2003. Incorporating ecological process and environmental change into spiny lobster population models using a spatially-explicit, individual-based approach. Fisheries Research 65: 63-79
	Ehrhardt, N.M. and Deleveaux ,V.K.W. 2008. Management of Fishing Capacity in a spiny lobster (*Panulirusargus*) Trap Fishery:Analysis of Trap Performance under the Florida Spiny Lobster Trap Certificate Program
	Florida Fish and Wildl. Conserv. Comm., FWRI (2010)-Spiny lobster 246

Country	References
	Harper, D. E. 1995. The 1995 spiny lobster update of the trends in landings, CPUE, and size of harvested lobster
	Hunt, J.H. 1994 Status of the fishery for *Panulirus argus* in Florida
	Labisky, R., Gregory, D. and Conti, J. 1980. Florida's spiny lobster fishery: an historical perspective
	Leeworthy, V. R. 2001. Economic impact of the recreational lobster fishery in Monroe County. FMRI
	Lyons, W. G., Barber, D.G, Foster, S.M., Kennedy, F. S., Milano, G. R. 1981. The spiny lobster, *Panulirus argus*, in the middle and upper Florida Keys: population structure, seasonal dynamics, and reproduction. Florida Marine Research Publications. No. 38
	Manoj P. Shivlani, J. Walter Milon (2000): Sociocultural Effects of a Market-Based Fishery Management Program in the Florida Keys, Coastal Management, 28:2, 133-147
	Matthews, T. R. 2001. Trap-induced mortality of the spiny lobster, *Panulirus argus* in Florida, USA. Mar. Freshwater Res.52, 1509-16
	Milon, J.W., S.L. Larkin, D.J. Lee, K.J. Quigley, and C.M. Adams. 1998. "The Performance of Florida's Spiny Lobster Trap Certificate Program." Florida Sea Grant Report Number 116.
	Milon, J.W., D.O. Suman, M. Shivlani, and K. Cochran. 1997. "Commercial Fishers' Perceptions of Marine Reserves for the Florida Keys National Marine Sanctuary." Florida Sea Grant publication TP-89.
	Muller, R. G., Hunt, J.H., Matthews, T.R. and Sharp, W.C. 1997. Evaluation of effort reduction in the Florida Keys spiny lobster *Panulirus argus*, fishery using an age-structured population model. Marine Freshwater Research. 48
	SEDAR 8 Update Stock Assessment Panel. 2010. Stock assessment of spiny lobster, *Panulirus argus*, in the Southeast United States
	Shivlani, M., Ehrhardt, N., Murray, T., Kirkley, J.2004. Assessment of the socioeconomic impacts of the Spiny Lobster Trap Certificate Program, spiny lobster fishery management efforts, and other spiny lobster user groups on individual commercial spiny lobster fishers
	Shivlani, M. 2010. Impact of Non-fishery Factors on the Performance of Commercial Fisheries: Case Study of the Florida Keys, 1950-2007. GCFI Proceedings 62.
Venezuela	AROCHA PÉREZ, Dulce. Pesquería de langosta en Venezuela: Fortalecimiento de la estructura pesquera y evaluación biológica pesquera. Informe técnico. 2012. 124 p. Informe de la Gerencia de Ordenación Pesquera, Insopesca 2012.
	Insopesca. 2012. Base estadística de la Gerencia de Ordenación Pesquera.