SEDAR

Southeast Data, Assessment, and Review

Stock Assessment Report
of
SEDAR 8

Southeastern US Spiny Lobster

SEDAR8
Assessment Report 3

2005

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SEDAR 8 Stock Assessment Report III.

Southeastern United States Spiny Lobster

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SECTION I. Introduction

SEDAR
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1. SEDAR Overview

SEDAR (Southeast Data, Assessment and Review), is a process developed by the Southeast Fisheries Science Center and the South Atlantic Fishery Management Council to improve the quality and reliability of stock assessments and to ensure a robust and independent peer review of stock assessment products. SEDAR was expanded in 2003 to address the assessment needs of all three Fishery Management Council in the Southeast Region (South Atlantic, Gulf of Mexico, and Caribbean), and to provide a platform for reviewing assessments developed through the Atlantic and Gulf States Marine Fisheries Commissions and state agencies within the southeast.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment workshop, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. SEDAR workshops are organized by the SEDAR staff and the lead Council. Data and Assessment Workshops are chaired by the SEDAR coordinator. Participants are drawn from state and federal agencies, non-government organizations, Council members and advisors, and the fishing industry, with a goal of including a broad range of disciplines and perspectives. The Review Workshop is chaired by a scientist selected by the Center for Independent Experts, an organization that provides independent, expert review of stock assessments and related work. Other participants include one reviewer from the CIE, one from the SEFSC, one from NOAA fisheries, one NGO representative, one or more Council Advisory panel representatives, and one or more Council technical (SSC or other panel) representatives.

This assessment, eighth in the SEDAR series, is charged with assessing Caribbean stocks of yellowtail snapper and spiny lobster. The Review Workshop will also consider an assessment of Atlantic and Gulf of Mexico spiny lobster conducted by the State of Florida through a SEDAR workshop format with assistance from the Gulf of Mexico and South Atlanatic Fishery Management Councils and NOAA Fisheries.

2. Document Overview

This document is a compilation of reports prepared by the data and assessment workshops convened by the State of Florida to assess spiny lobster in the Southeastern United States. It also includes the complete Review Workshop Consensus Report.

Stock Assessment Summary Report for Southeast United States Spiny Lobster

SEDAR 08 Stock Assessment Panel

2 May 2005

1. Introduction

This document summarizes the stock assessment report entitled "Assessment of spiny lobster, *Panulirus argus*, in the Southeast United States" prepared by the SEDAR 08 U.S. Spiny Lobster Stock Assessment Panel. By necessity, this summary also includes material from the Data Workshop Report. This document should be viewed as a brief overview of the assessment report and the reader is referred to that document for more detailed information.

2. Data

Relevant data on spiny lobsters was compiled at the Data Workshop that was held 25-27 January 2005 in Marathon, Florida under the auspices of the Florida Fish and Wildlife Conservation Commission. These data included life history information such as stock identification, growth estimates from tagging and lipofuscin concentrations, reproduction, natural mortality rates, as well as fishery characteristics.

Briefly, Caribbean spiny lobsters spend 6-9 months after hatching as larvae (phyllosoma) in the plankton after which they settle onto suitable substrate and metamorphose into juveniles. They spend about 18 months to two years in nursery areas before they migrate to the offshore reefs where spawning occurs. Oceanographic features such as the Caribbean Current, the Loop Current, and the Florida Current have the potential to transport the larvae from the eastern Caribbean to the Florida Straits in approximately 90-100 days. Not surprisingly, genetic studies have shown very high diversity in spiny lobsters such that no geographic differences could be inferred other than that the spiny lobster in Brazil could be a separate sub-species but the Brazilian form has been collected off Miami, Florida. What this means for stock assessment is that recruitment in Southeast United States probably includes animals from upstream of Florida in addition to local production making the spawning stock undefined.

The fishery for spiny lobster in the Southeast United States began in Florida in the late 1800s and the earliest recorded landings were in 1897 from Key West (Fig. 1). The fishery originated as an artisanal and bait fishery for finfish; later with the advent of the railroad providing access to markets, spiny lobster became a food fishery. Traps became the dominant gear in the 1920s and the fishery first exceeded a million pounds in 1941 with landings of 2.1 million pounds (947 metric tons). In 1965, the minimum carapace size was reduced to 3 inches (76.2 mm) that reduction opened Florida Bay to fishing adjacent to the nursery areas. After an adjustment period, annual commercial landings have varied around an average of 2500 mt (5.5 million pounds) since 1969.

Data from fishery-dependent and -independent sampling programs were presented. The fishery-dependent sampling included length samples from the commercial and recreational fisheries through interviews and trap length composition and catch rates through observers. Fishery-independent sampling included monitoring puerulus settlement (the first non-planktonic stage), more than 20 years of juvenile and recruitment studies, as well as diver and trap based sampling. Commercial landings came from NMFS General Canvass and Florida's Marine Resources Information System (trip tickets). Recreational landings have been estimated from mail-surveys since 1992 and landing reports from the Special Recreational Crawfish license holders since 1994. Traps were the dominant gear followed by the recreational divers (Fig. 2). These data were presented in the Data Workshop Report and appropriate data were included in the Stock Assessment Report.

Catch-at-length and catch-at-age matrices were unavailable at the Data Workshop but these were presented in the Stock Assessment Workshop. Also, panel members at the Stock Assessment Workshop made suggestions on improving the tuning indices and those changes were implemented in the assessment.

3. Stock Assessment

The Stock Assessment Workshop was held 15-17 March 2005 in Marathon, Florida. From the variety of models that were presented at the workshop, the panel members chose two assessment models: a simple, modified DeLury model and a statistical catch-at-age model (Integrated Catch-at-Age). The age-structured model was the base model and the DeLury model was a check for consistency. The DeLury model used numbers of fish and effort by fishing year extended back to the 1978-79 fishing year (Table 1). Both models used fishery-dependent (observer and Biscayne National Park creel survey) and fishery-independent (puerulus and adult monitoring) tuning indices (Table 2). Sensitivity runs included running the age-structured model with two lipofuscin growth curves and with two alternative natural mortality rates. Retrospective analysis compared patterns in fishing mortality rates, recruitment, and population sizes in terminal years from 1997-98 to 2002-03 to the base run results.

Recruitment of lobsters one year after settlement has varied over the time series (Fig. 3). The spawning biomass in Florida has increased over time especially in the three most recent fishing years (Fig. 4). Fishing mortality rates have varied without trend until the recent drop in fishing mortality after 2000 (Fig. 5). Older lobsters appear to be less available to the fishery as reflected in the dome-shaped selectivity curve (Fig. 6). Both assessment models interpreted the lower landings after the 1999-00 fishing year as decreased effort. The DeLury model estimated a lower population size with correspondingly higher fishing mortality rates than did ICA but when the DeLury was adjusted for selectivity, the results were similar (Fig. 7). We did not fit stock-recruit relationships to either model because the spawning biomass in Florida forms an unknown portion of the spawning stock that produced the recruits reaching Florida. The retrospective analyses indicated that fishing mortality rates from ICA were initially underestimated by an average of 37%.

4. Stock Status

Amendment 6 of the Spiny Lobster FMP defined overfishing as fishing at a rate in excess of that associated with a static SPR value of 20% (F20%). With the current life history values and fishery practices, the fishing mortality rate on fully recruited lobsters (age-3) at a static SPR of 20% was 0.49 per year. The spiny lobster fishery in Southeast United States has fluctuated at SPR values around the 20% objective until the three most recent years (Fig. 8) and was deemed to not be overfishing because the fishing mortality rate on age-3 in 2003-04 (0.26 per year) was below the Council's Fmsy proxy of F20%. Even when the fishing mortality rate was adjusted for retrospective bias (0.36 per year), the fishing mortality rate in 2003-04 was still below the Council's management objective. As noted above, without a Caribbean-wide stock assessment, we were unable to determine the status of the stock with regard to the spawning biomass at MSY (Bmsy) or the Minimum Stock Size Threshold.

Table 1. The landings, in numbers, and effort by sector and fishing year used in the DeLury model.

Fishing Season	Recreational Landings	Commercial Landings	Bait Landings	Total Landings	Recreational Person-days	Commercial Trips
1978-79	1032818	4712160	1489053	7234031	298427	32833
1979-80	1332146	6384958	1766902	9484006	384930	44488
1980-81	1653054	5074434	1450653	8178140	479513	35357
1981-82	1438200	4673563	1389579	7501342	416247	32564
1982-83	1487598	5192189	1440506	8120294	430799	36177
1983-84	1114641	3516013	1205460	5836114	322088	24498
1984-85	1218015	5077610	1458513	7754138	350689	35379
1985-86	1176734	4586067	932611	6695412	339625	32351
1986-87	1098768	3955795	1321591	6376154	317518	31082
1987-88	1305427	4657778	521939	6485144	377255	34407
1988-89	1743948	6381104	499015	8624067	505243	36431
1989-90	1718020	6650042	587191	8955253	497125	40276
1990-91	1496810	5154258	1061504	7712572	433092	40537
1991-92	1990623	5784865	662668	8438156	578003	45773
1992-93	1242648	4567343	565406	6375396	481276	35818
1993-94	1787054	4662274	422617	6871945	518641	31568
1994-95	1751298	6229495	492439	8473232	550898	32554
1995-96	1673330	5666412	513035	7852777	472707	32830
1996-97	1778889	6646664	583692	9009244	545809	32849
1997-98	2186058	6796320	621140	9603518	323006	34087
1998-99	1185036	4522375	275976	5983388	337574	26198
1999-00	2292304	6581944	498148	9372396	560140	28142
2000-01	1848447	4469964	423038	6741450	470467	26248
2001-02	1091022	2307262	323096	3721380	370026	19669
2002-03	1223197	3818081	347857	5389136	345777	24186
2003-04	1142960	3419929	329668	4892558	359214	22232

Table 2. Tuning indices and the ages that they were applied to in the age-structured models used in assessment analyses. The Biscayne National Park creel survey, observer and adult monitoring pre-recruit, and puerulus indices were recalculated based on recommendations from the Data Workshop and the Stock Assessment Workshop.

	Fishery dependent						Fishery independent					
Fishing year	Legal-sized Observer Ages 3+ Number/trap	CV	Pre-recruit Observer Age 2 Number/trap	CV	Biscayne National Park Ages 2+ Number/trip	CV	Legal-sized Adult Monitoring Ages 3+ Number/dive	CV	Pre-recruit Adult Monitoring Age 2 Number/dive	CV	Puerulus Age 1 Number/collector	CV
1978-79					20.24	1.161						
1979-80					16.43	1.443						
1980-81					16.65	1.255						
1981-82					13.72	1.526						
1982-83					12.52	1.448						
1983-84					10.86	2.154						
1984-85					11.17	2.430						
1985-86					8.99	3.903						
1986-87					6.63	2.658						
1987-88					7.29	3.519					12.53	6.76
1988-89					7.43	3.509					13.41	6.85
1989-90					7.51	3.379					19.47	5.92
1990-91					6.76	2.409					13.59	7.12
1991-92					10.33	1.853					12.05	5.93
1992-93					7.84	3.298					12.46	7.99
1993-94	0.70	0.852	2.11	0.478	13.26	1.757					13.14	5.72
1994-95	1.14	0.920	2.24	0.636	10.13	1.947					14.36	6.12
1995-96	1.00	0.815	2.16	0.601	13.10	1.986					14.12	5.74
1996-97	1.08	0.930	2.60	0.604	11.01	1.689					8.57	6.77
1997-98	1.27	0.876	2.71	0.578	17.04	1.363	11.21	7.01	11.15	7.02	14.59	6.19
1998-99	1.08	0.964	3.15	0.601	13.53	1.634	11.45	6.72	4.91	10.12	18.20	5.31
1999-00	0.93	1.539	2.60	0.865	22.97	1.604	21.88	4.87	14.58	5.97	11.16	6.06
2000-01	0.86	1.162	2.31	0.725	12.69	1.559	23.05	4.96	11.01	7.13	13.31	5.84
2001-02					8.90	2.161	17.36	5.46	5.12	9.91	10.55	6.09
2002-03					12.98	1.926	14.32	5.82	6.26	8.69	11.42	6.18
2003-04					10.01	1.917	19.60	5.12	5.01	9.96	8.80	6.62
2004-05					12.30	1.812						

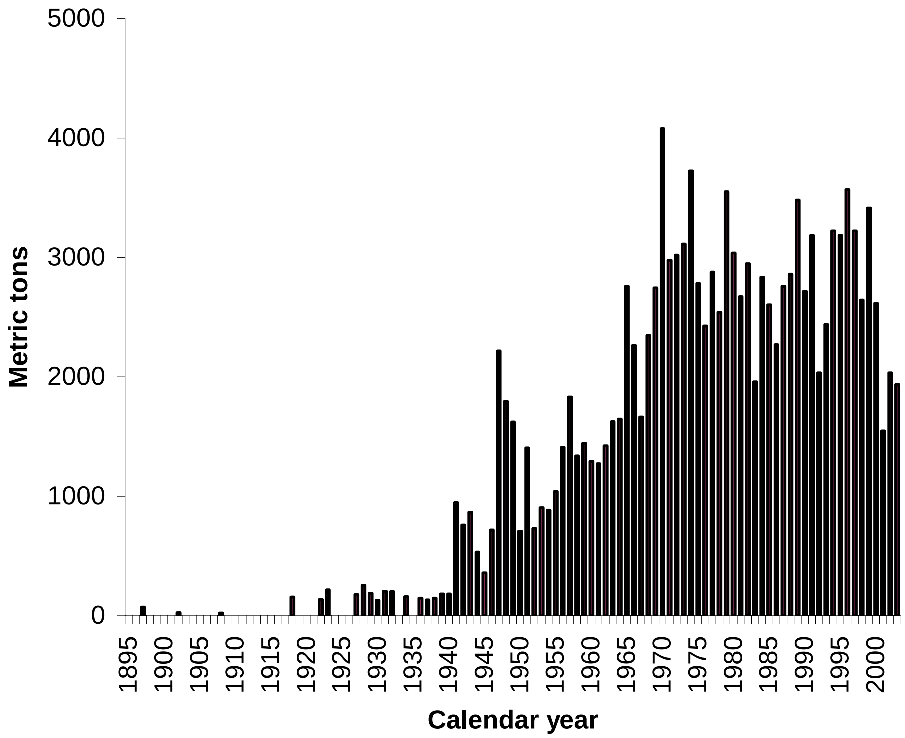


Figure 1. Commercial landings of spiny lobster in the United States.

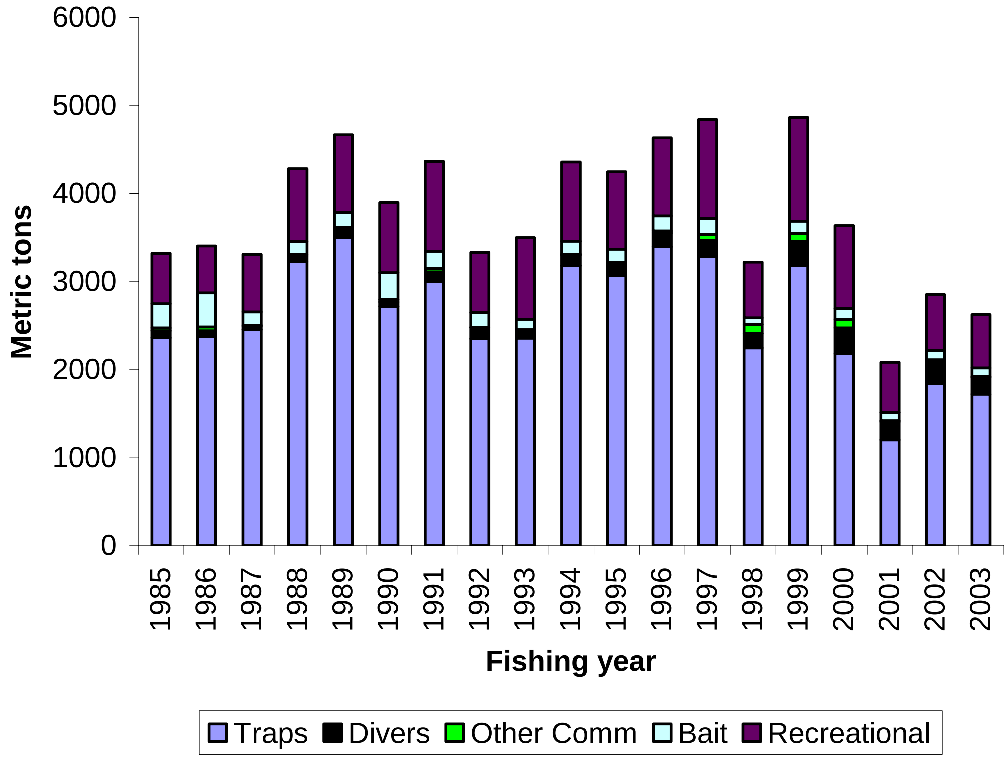


Figure 2. Harvest of spiny lobster in Southeast United States by gear and fishing year.

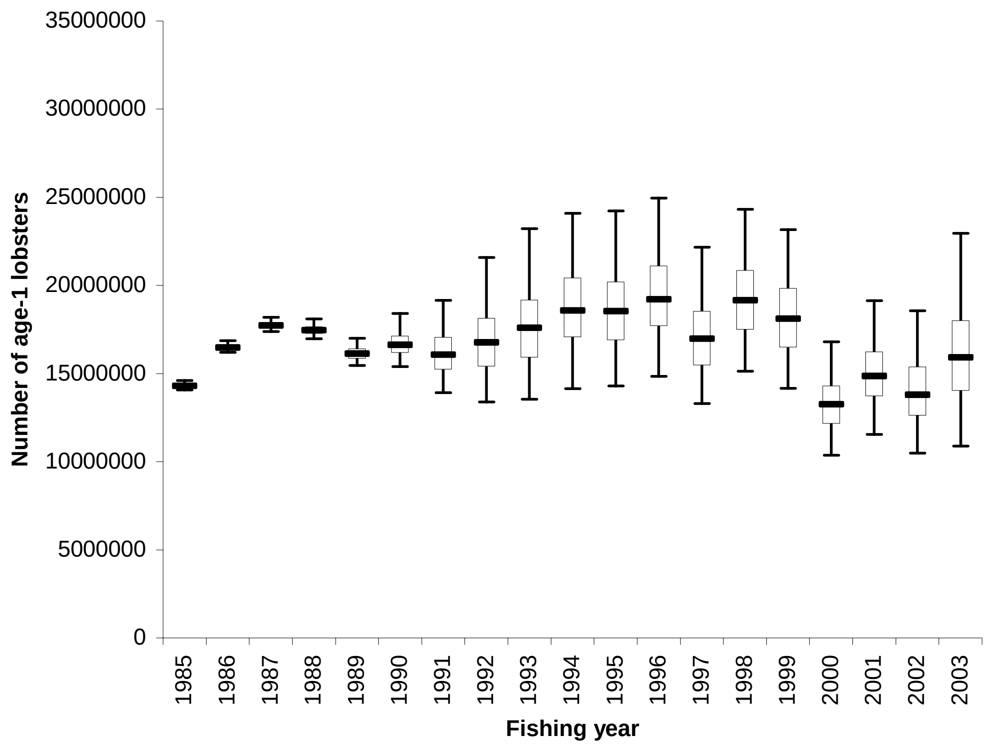


Figure 3. The number of age-1 recruits based on 1000 Monte Carlo runs using the covariance matrix. The vertical lines are the 95% confidence intervals, the boxes are the inter-quartiles (25 to 75 percentiles) and the horizontal lines are the medians.

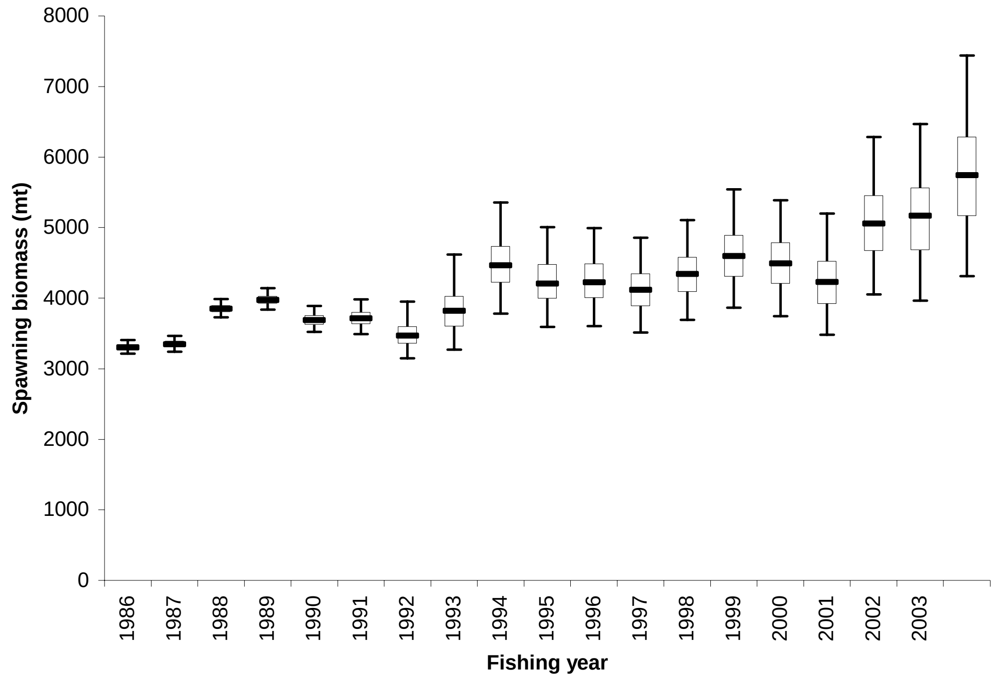
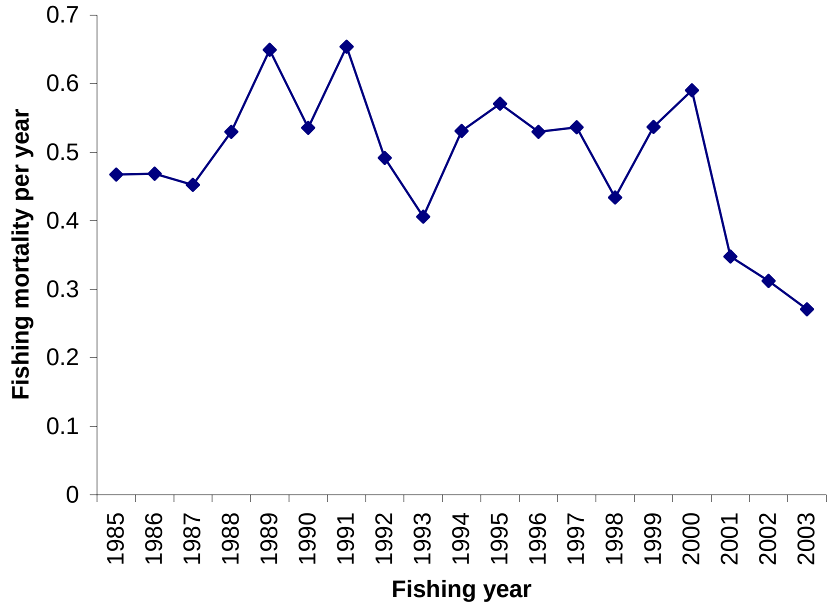


Figure 4. Spawning biomass in Florida by fishing year. The vertical lines are the 95% confidence intervals, the boxes are the inter-quartiles (25 to 75 percentiles) and the horizontal lines are the medians.

a. Fishing mortality per year on age-3 lobsters



b. Average fishing mortality on ages 1-5

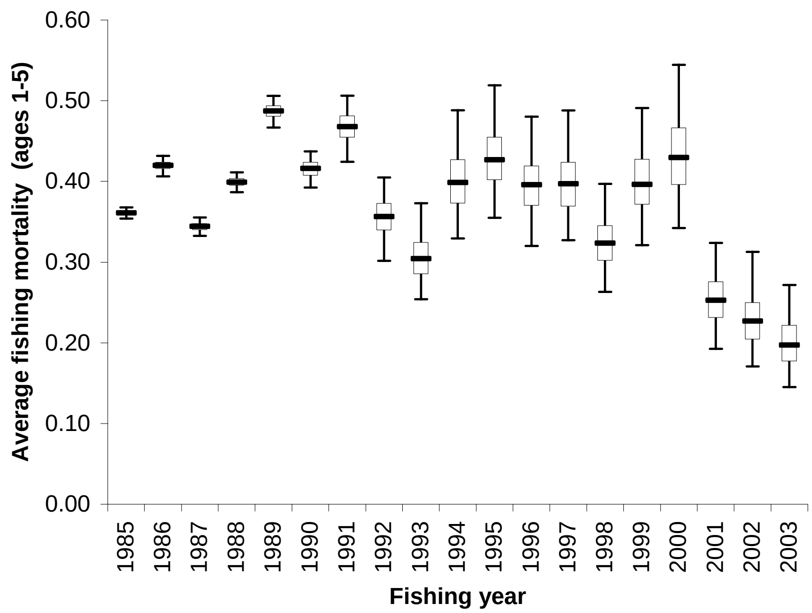


Figure 5. Fishing mortality rates estimated by ICA. The uncertainty in the average fishing mortality rates is based on 1000 Monte Carlo runs using the covariance matrix. The vertical lines are the 95% confidence intervals, the boxes are the inter-quartiles (25 to 75 percentiles) and the horizontal lines are the medians.

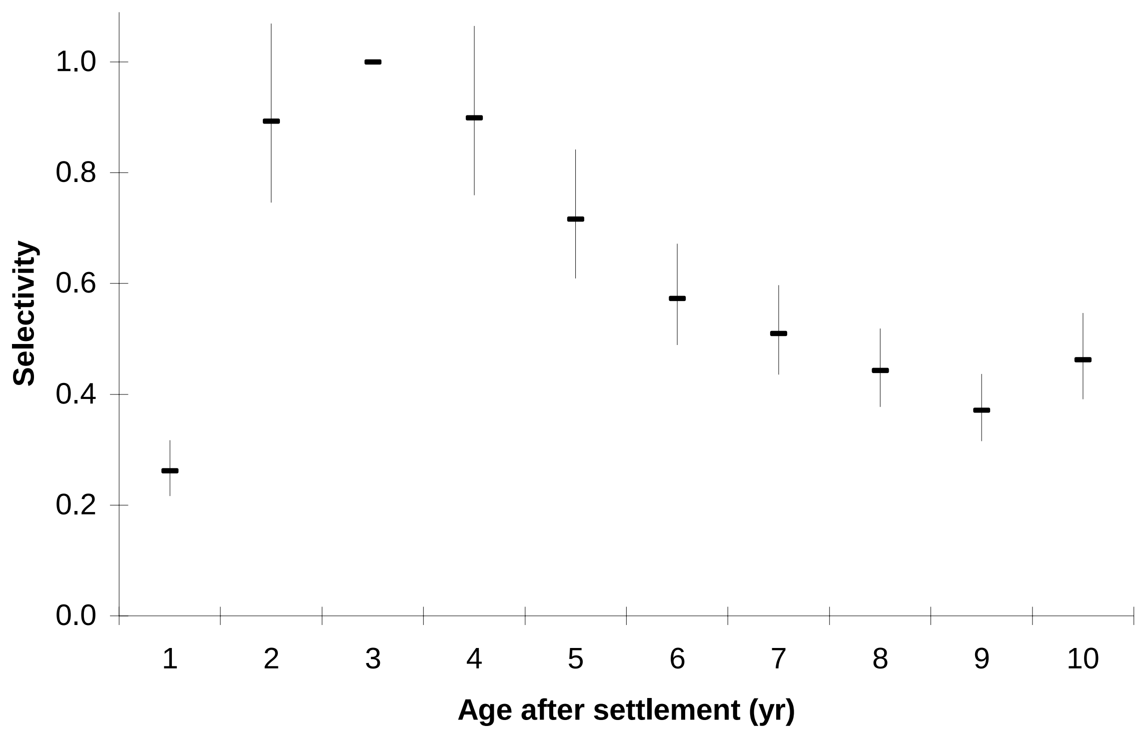


Figure 6. Selectivity by age for the period 1993-94 and later. The vertical lines are the 95% confidence interval and the horizontal lines are the maximum likelihood point estimates.

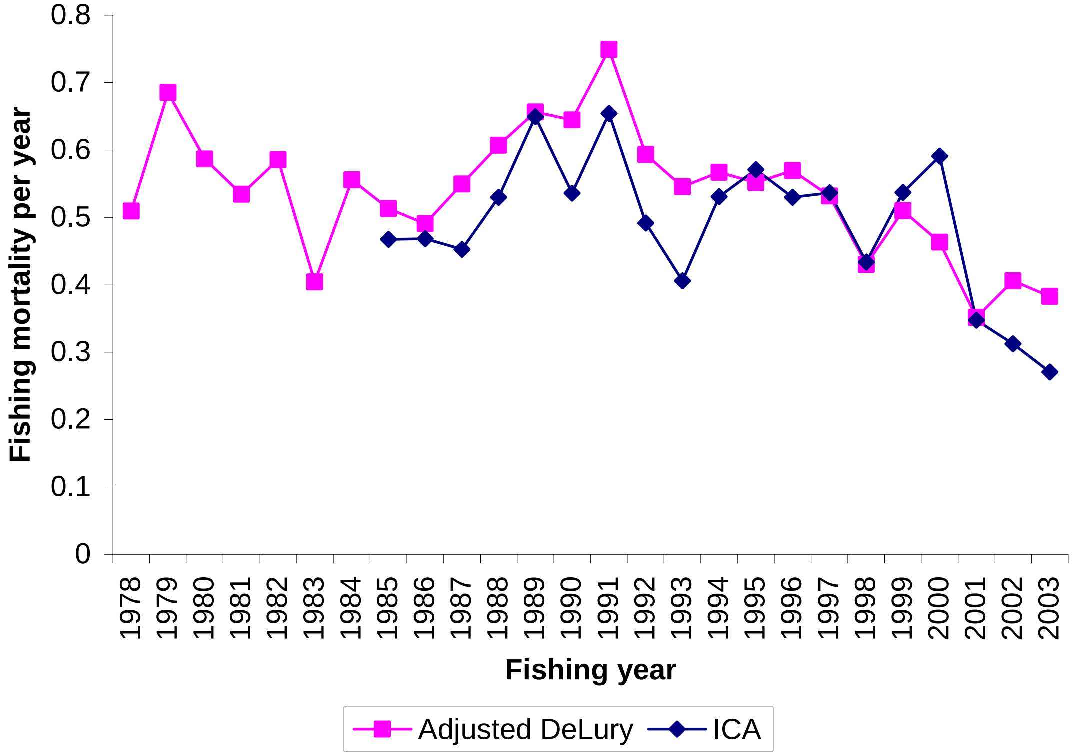


Figure 7. Comparison of the fishing mortality rates from the selectivity adjusted DeLury model and the age-structured model ICA.

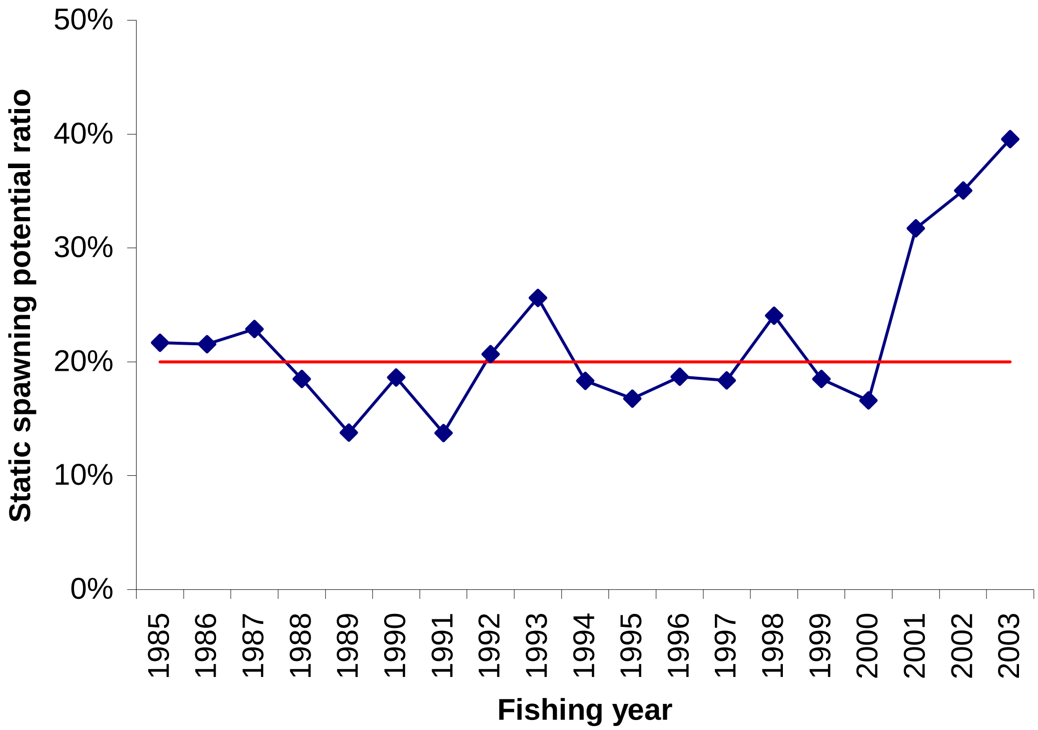


Figure 8. Static spawning potential ratios by fishing year and the current management objective of 20%.

SEDAR 8

Stock Assessment Report III

Southeastern US Spiny Lobster

SECTION II. Data Workshop

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Southeast Data, Assessment, and Review (SEDAR)
Data Workshop on Spiny Lobster

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
Marathon, FL

January 25-27, 2005

Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

Table of Contents

1.0 Introduction

The Florida Fish and Wildlife Conservation Commission is the primary manager of spiny lobsters in the State of Florida. The key biological management measures are a minimum size (3 inches carapace length), closed season during the bulk of the reproductive season (April – August), a prohibition of taking of egg-bearing females, and various measures designed to reduce discard mortality (use of live wells on vessels transporting sub-legal lobsters; prohibition of spearing, etc). The commercial fishery is regulated through an effort management program designed to control and reduce the total number of traps used in the fishery. Trap numbers have declined from approximately 900,000 just prior to the implementation of this program in 1993 to slightly fewer than 500,000 today. However, a commercial dive fishery has flourished in recent years and the recreational fishery remains large. Allocations between these sectors have shifted in recent years prompting a constant tweaking of the management plan. In response, the Commission directed staff to conduct a three-year comprehensive review of the fishery from both an assessment and management perspective. Any and all management options could be considered during this process. One decision was to place our assessment into the SEDAR process to bring in new data where available, to bring in the active partnership with stakeholders in the assessment process, and possibly to build new assessments into the overall evaluation of the fishery. Once this is complete, the Commission will use the outcome from the assessment to reevaluate all aspects of the management plan in partnership with stakeholders.

1.1 Workshop Time and Place

The workshop was held in Marathon, Florida at the Florida Fish and Wildlife Conservation Commission - South Florida Regional Laboratory from January 25 through January 27, 2005.

1.2 Terms of Reference

1. Determine the quality and appropriateness of life-history information.
    - Address the following items:
        - Stock structure and unit stock identification
        - Natural mortality
        - Ageing methods, age structure sampling, and age determinations
        - Growth models
        - Reproductive characteristics: sex ratio including, maturity, and fecundity

2. Determine the quality and appropriateness of stock abundance indices (Trip Interview Program CPUE, puerulus index, observer program, etc.).
    - Provide the following:
        - Summary of survey methods, especially noting any changes
        - Details of sampling intensity and coverage
        - Maps of area and depths sampled
        - Survey values

3. Determine the quality and appropriateness of fishery data.
    - Provide the following:
        - Annual landings by appropriate strata
        - Biological sampling details (intensity, coverage)
        - Length and age distributions
        - Discard rates, release mortality, and estimated discard removals

4. Provide a review of past assessment methods.

5. Determine the quality and appropriateness of available data for estimating impacts from proposed or existing management measures.

6. Recommend possible assessment methods and appropriate models given the quality and scope of the data sets reviewed.

7. Provide recommendations for future research (field and assessment).

8. Prepare a Data Workshop Report based on the SEDAR Assessment Report Outline and addressing the Terms of Reference and providing DW endorsed datasets. Submit the report to SEDAR within 4 weeks of the conclusion of the workshop.

1.3 List of Participants

Beaver, Rick	Gaitanis, Robert	Little, Ed
Bertelsen, Rod	Gaitanis, Tom	Matthews, Tom
Boragine, Ralph	Gregory, Doug	Maxwell, Kerry
Braynard, Shelli	Harper, Doug	Moe, Martin
Butler, Mark	Hunt, John	Muller, Bob
Cox, Carrollyn	Iarocci, Tony	Piton, Ernie
Cramer, Jeff	Irwin, Bruce	Sharp, Bill
Cufone, Marianne	Jackson, Anne	Slade, Stopher
Dolan, Tom	Johnson, Eric	Stafford, Simon
Ehrhardt, Nelson	Kennedy, Stu	Williams, Roy

(See Appendix A for contact information)

2.0 Biological Characteristics

2.1 Life History

<u>2.1.1 Stock Distribution</u>

The Caribbean spiny lobster (*Panulirus argus*) occurs throughout the Caribbean Sea, along the shelf waters of the southeastern United States north to North Carolina, in Bermuda, and south to Brazil and the Gulf of Mexico. The origins of the Florida stock remain unknown as information on larval recruitment remains scarce. However, Lyons (1981) concluded that, given the constant recruitment to the fishery despite the reduction in spawning potential of the Florida stock, larval recruitment to the region is in large part exogenous. That conclusion is supported by examination of the genome of *P. argus* populations from Venezuela to Bermuda (Silberman et al., 1994). Restriction fragment length polymorphism analysis of mtDNA identified no differentiation between populations, suggesting a single pan-Caribbean *P. argus* stock, though populations in Brazil are genetically distinct from Caribbean populations and may represent a subspecies, *P. argus westonii* (Sarver *et al*., 1998). Larvae originating in most locations have potential to be carried long distances before settlement, and Florida populations may be connected to populations in South America and the Caribbean by intermediate populations in West Africa or by complete larval circumnavigation of the North Atlantic gyre (Silberman et al., 1994).

<u>2.1.2 Habitat Requirements and Distribution Patterns</u>

Panulirus argus is a highly migratory palinurid lobster species with a complex life cycle in which distinctly different habitats are occupied during ontogeny. After spawning, the oceanic phyllosome larvae spend an estimated 9 months (Butler and Herrnkind, 1992), in the plankton, potentially dispersing thousands of kilometers. Because of the potential for *P. argus* larvae to be transported such enormous distances, understanding the factors that affect their distribution during this stage is complex and remains poorly understood. Extensive effort has been directed at understanding the recruitment dynamics of *P. argus* in south Florida, especially in Florida Bay and along the Florida Keys archipelago, which is the largest and most important expanse of nursery habitat for the species in the region (Davis and Dodrill, 1989). These studies have documented that late-stage larvae concentrate at the edge of the Florida Current, and it is there that puerulus post-larvae are first observed (Yeung and McGowan, 1991). *Panulirus argus* pueruli are nocturnally active and efficient swimmers capable of speeds of 10 cm/s (Calinski and Lyons, 1983). Recruitment to inshore environments occurs all year round into Florida Bay and nearby regions in monthly pulses coincident with the new moon (Heatwole *et al.,* 1991; Forcucci *et al*., 1994). How pueruli orient toward shore remains poorly understood, but laboratory trials have demonstrated that the detection of coastal chemical cues may be important (Goldstein and Butler, 2004). Upon recruiting to near-shore waters, *P. argus* post-larvae preferentially settle into dense vegetation, especially the architecturally complex macroalgae, *Laurencia* spp. Seagrass meadows also function as settlement habitat (Acosta, 1999; Sharp *et al*., 2000), but the subsequent survival of lobsters settling there appears to be lower compared to those that settle within macroalgae (Herrnkind and Butler, 1986). Temperature and salinity regimes restrict *P. argus* settlement to the southernmost reaches of the Bay (Field and Butler, 1994). In other areas in the Caribbean, *P. argus* may also settle on mangrove prop roots (Acosta and Butler, 1997).

Once settled, *P. argus* pueruli metamorphose into the first benthic instar [~ 6mm carapace length (CL)] (Marx and Herrnkind, 1985; Butler and Herrnkind, 1991; Forcucci, *et al.,* 1994). These "algal-stage" juveniles reside solitarily within vegetation until reaching 15-20mm CL, then emerge and take up refuge in crevice shelters provided by large sponges, octocorals, and solution holes. These "post-algal" juveniles occupy a relatively small home range within the nursery until they reach about 35mm CL, and then become increasingly nomadic (Herrnkind and Butler, 1986). At about 50-80 mm CL lobsters begin to move from the inshore nursery habitat to coral reefs and other offshore habitats (Hunt and Lyons, 1986).

2.1.3 Natural Mortality

Estimates of natural mortality in all lobster stocks have historically proven difficult to assess and current data specific to *P. argus* is fairly scarce. The pattern that emerges from a variety of methods and historical data indicates that most reliable estimates for M range between 0.3-0.4 $year^{-1}$ (Table 1) and the average natural mortality in Florida would likely fall within this range (FAO, 2001).

Table 1. Estimates of natural mortality ($year^{-1}$) (Table taken from FAO, 2001)

Country	Sex	Method	M	Author
Bahamas	M+F	?	0.36	Ehrhardt
Brazil	M+F	Pauly (1980)[3]	0.30	Ivo (1996)
Colombia	M	Empirical formula[2]	0.54	Gallo *et al.* (1998)
	F		0.51	
	M+F		0.62	
Cuba	M+F	Tagging	0.26	Buesa (1972)
	M+F	Tagging	0.44	Cruz *et al.*, (1986a)
	M+F	Empirical formula[2]	0.34	Cruz *et al.* (1981)
Florida, USA	M+F	Pauly (1980)[3]	0.42	Powers and Sutherland (1989)
Florida, USA	M+F	Longevity	0.30	Muller *et al.* (1997)
Jamaica	M	Pauly (1980)[3]	0.59	Haughton (1988)
	F		0.67	
	M+F		0.62	
Nicaragua	M	Empirical formula[2]	0.41	Estimated during the 1998 working group session
	F		0.50	
	M+F		0.45	
Virgin Is.	M	Tagging	0.46	Olsen and Koblic (1975)
	M		0.43	
	F		0.52	
Turks & Caicos	M+F	Depletion model[4]	0.36	Medley and Ninnes (1997)

[1]The working group used as an average value for longevity of 13.9 years from Ivo (1996), in conjunction with the model for natural mortality of Hoenig (1983) where the relation between Z and longevity (Tm) is: Z = 1.46 - 1.01 Tm 1.01 .

[2]Cruz *et al* (1981) developed an empirical equation to estimate crustacean natural mortality based on mortality and growth parameters and mean water temperature from a number of data sets, similar to Pauly's equation used for finfish:

$M = 0.0277 - 0.0004 * L\infty + 0.5397 * K + 0.0119 * T$

Where L∞ = CL (mm), K = Growth rate (year-1) and T = Temperature (oC). Using this equation, M values for the region range between 0.3 and 0.35 year-1 .

[3]Pauly's (1980) method was developed for finfish and is unreliable for crustaceans, which may explain the generally higher values obtained through this method. Where possible, these values should be re-estimated using Cruz *et al.*(1981) method.

[4]The depletion model provides an estimate independent of growth models and size data.

2.1.4 Food Habits

Little is known about the natural forage of larval stages, but observations of cultured *P. argus* larvae and those of related species suggest they are adapted to feeding upon soft-bodied plankton. Cultured *P. argus* larvae have been observed to prey upon fish larvae (Moe, 1991), and feeding experiments with other palinurid lobster species have documented larvae successfully preying upon gelatinous organisms (Kittaka, 1997). Cultured larvae have also been successfully raised on *Artemia* naupuli and pieces of mollusk (Kittaka, 1997).

All benthic stages of *P. argus* feed preferentially upon mollusks, especially gastropods, and crustaceans, but will consume a wide variety of invertebrates (Marx and Herrnkind, 1985; Cox, *et al*., 1997).

2.1.5 Reproductive Life History

Mating and spawning of *P. argus* in the Florida Keys occurs on the offshore reef tract, principally from April through September (Bertelsen and Cox, 2001; Lyons *et al*., 1981; Davis, 1974). The onset of population-wide reproductive maturation of female lobsters, estimated as the size at which 50% of the population is ovigerous during the peak of the reproductive season, occurs at about 70-75 mm CL, though females as small as 57 mm CL have been observed bearing eggs (Bertelsen and Matthews, 2001). The onset of population-wide functional maturity in males, estimated by the onset of allometric growth of the second pair of walking legs, has been estimated to occur at 98 mm CL (FWC unpublished data). Mating and spawning behavior appear, in part, controlled by environmental factors. Increased day length and water temperatures have been shown to enhance courtship and the frequency of spawning (Lipcius and Herrnkind, 1987). There are generally size-specific patterns in mating and spawning. Larger females generally mate, spawn eggs, and release larvae, earlier in the reproductive season than smaller mature females (Lipcius, 1985; Bertelsen and Matthews, 2001). Smaller adult males molt early in the reproductive season, while larger males mate (Lipcius, 1985).

Size-specific differences in the onset of reproductive maturity of female *P. argus* have been noted between the lobster populations in the Florida Keys and the Dry Tortugas. The lobster population in the latter region has historically endured much lower fishing pressure and consequently, the size-structure of the lobsters there is larger than that in the Florida Keys. Females in the Dry Tortugas begin producing eggs at a much larger size than do those in the Florida Keys. It has been speculated that lobsters in both regions begin to produce eggs at the same chronological age, but fishery practices have resulted in comparatively slower growth rates in Florida Keys lobsters (Bertelsen and Matthews, 2001).

2.1.6 Disease

There are four diseases known to infect *P. argus*, but there are undoubtedly more that have not been discovered (Evans et al. 2000, Porter et al. 2001, Shields and Behringer 2004). Three of the four known diseases were reported from *P. argus* populations in Florida: shell disease (Porter et al. 2001), microsporidiosis (Bach and Beardsley 1976), and the PaV1 virus (Shields and Behringer 2004). The fourth, gaffkaemia, occurs in Cuba (Bobes et al. 1988). Shell disease is caused by a variety of bacteria, most of which are rod-shaped, Gram-negative strains that exhibit chitinolytic activity, which causes necrotic lesions on the chitin-rich exoskeleton (Porter et al. 2001). The disease is rarely lethal, its prevalence low, and its distribution in nature is typically limited to sites where water quality is poor and the host is stressed, or where fishing intensity and thus inadvertent damage to animals is severe. Microsporidiosis is caused by internal protistan parasites that infect the muscles and internal tissues of lobsters; in severe cases it is fatal

(Evans et al. 2000). An old and rather limited report of the disease in Florida (Bach and Beardsley 1976) suggests that the disease is associated with environmental stress. Gaffkaemia, a systematic disease caused by the Gram-positive bacterium *Aerococcus viridans var. homari*, is not known to occur in Florida. Where it does occur in other decapod crustaceans, it can be lethal and only develops in lobsters with breaks or wounds in the exoskeleton (Evans et al. 2000).

In 1999, the first naturally occurring pathogenic virus (PaV1) reported for any lobster species was discovered in juvenile *P. argus* in the Florida Keys (Shields & Behringer 2004). The systemic disease is caused by an unenveloped, icosahedral DNA virus that attacks certain hemocytes (blood cells) but also infects soft connective tissue cells, and fixed phagocytes. In the late stages of disease, lobsters are moribund and their normally clear hemolymph (blood) becomes chalky white with cellular debris. The virus is pathogenic and lethal with lobsters apparently dying within 90 days from metabolic wasting and a loss of energy reserves. Laboratory experiments indicate that the virus is transmitted most effectively by direct contact with infected individuals, but can also be contracted via ingestion of infected tissue (Behringer 2003). Limited transmission in the water over very short distances (< 1m) also appears possible (Butler et al. 2004).

In semi-annual surveys of juvenile lobsters conducted since 1999 at 12 sites in the Florida Keys, prevalence of PaV1 infection has been as high as 30%, with a mean prevalence of 7% per site (Behringer 2003). Surveys of juvenile lobster populations at over 100 sites throughout the Florida Keys in 2002 and 2003 indicate that the disease was present at 20% of the sites with a mean prevalence of 5% at each site (Butler et al. 2004). The disease is most frequent (mean = 16%) among the smallest crevice-dwelling juveniles (<20mm CL); its prevalence in early benthic juveniles in the field is unknown, but laboratory evidence suggests that it is likely to be even higher than in larger juveniles. In contrast, less than 1% of the 1548 adults sampled by FWC along the Florida Keys reef tract in 2001 presented visual signs of infection and those that were infected were considered “adolescent” and probably recently arrived at the reef. Limited laboratory experimentation with adults suggest that adults are more resistant to the disease than juveniles, but adults can be infected via inoculation (Butler et al. 2004). Histological examination of > 300 postlarvae from the plankton suggest that they are not infected when they enter the ecosystem, but this needs to be confirmed using molecular viral markers (Butler et al. 2004).

The social behavior of larger juvenile and adult *P. argus* potentially hastens the transmission of disease, be it by water-borne particles, direct contact, proximity to a diseased carcass, or ingestion of infected tissue. However, in the field, juveniles infected with PaV1 are typically found alone in dens more often than healthy juveniles and laboratory experiments confirm this change in aggregation is attributed to the disease. Healthy juvenile lobsters avoid cohabitation with severely diseased conspecifics, presumably responding to alterations in the chemical cues produced by diseased individuals. (Shields and Behringer 2004).

2.1.7 Morphometrics

A comprehensive group of morphometric equations have been developed for *P. argus* to allow conversions to be made between carapace length, tail length, total length, tail width, fresh and frozen tail weight, and fresh and frozen whole weight (Matthews et al. 2003). Such equations were designed to allow fishery managers and enforcement personnel to convert various length and weight measurements (Table 1).

Table 2.1.7 (1). Morphometric equations for *Panulirus argus* form Florida

Variables	Sex[1]	Regression Equation[2]
Carapace Length : Total Length	B	TTL=2.67∗CL+13.30
	M	TTL=2.51∗CL+22.19
	F	TTL=2.80∗CL+6.32
Tail Length : Total Length	B	TTL=1.56∗TL-5.72
	M	TTL=1.57∗TL-5.26
	F	TTL=1.57∗TL-7.89
Tail Length : Carapace Length	B	CL=0.58∗TL-7.13
	M	CL=0.62∗TL-10.95
	F	CL=0.56∗TL-5.07
	M<73mm	CL=0.58∗TL-5.66
	M>73mm	CL=0.62∗TL-9.48
Carapace Length : Total Weight	B	$TTWT=0.001989*CL^{2.80327}$
	M	$TTWT=0.002229*CL^{2.77012}$
	F	$TTWT=0.001839*CL^{2.82810}$
Total Length : Total Weight	B	$TTWT=0.00003671*TTL^{3.00056}$
	M	$TTWT=0.00002080*TTL^{3.10922}$
	F	$TTWT=0.00005812*TTL^{2.91274}$
Tail Length : Total Weight	B	$TTWT=0.00008379*TL^{3.08710}$
	M	$TTWT=0.00005494*TL^{3.17957}$
	F	$TTWT=0.00001059*TL^{3.03328}$
Total Weight : Carapace Length	B	$CL=9.1975*TTWT^{0.35673}$
	M	$CL=9.0640*TTWT^{0.36100}$
	F	$CL=9.2734*TTWT^{0.35359}$
Total Weight : Total Length	B	$TL=30.0684*TTWT^{0.33327}$
	M	$TL=32.0479*TTWT^{0.32162}$
	F	$TL=28.4571*TTWT^{0.34332}$
Total Weight : Tail Length	B	$TL=20.9218*TTWT^{0.32393}$
	M	$TL=21.8696*TTWT^{0.31451}$
	F	$TL=20.4409*TTWT^{0.32968}$

[1] B = both sexes included, M = male, F = female
[2] TTWT = total weight, TTL= total length, CL= carapace length, TL = tail length, TW = tail width.

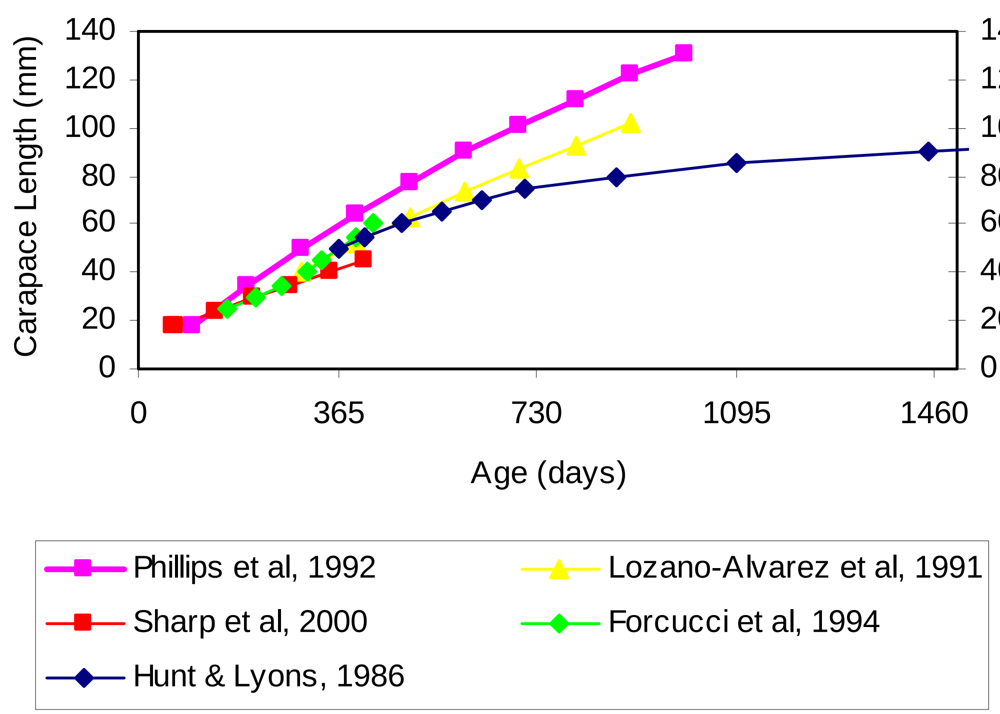
2.2 Age and Growth

2.2.1 Overview

Stock assessments strive to determine whether the rates of removals are offset by the rates of stock increase. Hence, we evaluate processes as changes-per-time or rates. Determination of the age and growth is critical to this process. For example, growth is the change in size or biomass of an animal with time. Unfortunately, Caribbean spiny lobsters grow by increments as they molt, so data on growth is not continuous and must incorporate molt interval as well. Lobsters and other crustaceans also do not have structures analogous to otoliths that record age. Another complexity is that spiny lobsters have several planktonic stages (phyllosoma) that may last anywhere from six months to one year, so age determination is often determined beginning with larval settlement.

Most estimates of growth for spiny lobster are based on tag recapture data. The results of several of the more recent studies are compared in Figure 1. Tagging studies may underestimate growth in two ways. The process of tagging a lobster can cause injury to the lobster which might reduce growth (Hunt and Lyons 1986) or affect the recapture rate if lobsters that molt less frequently preferentially retain tags. With the exception of Sharp et al., 2000 and Forcucci et al., 1994 these studies are mostly dependent on tag returns from the fishery which can also be a source of differential return rates. All of these factors may have contributed to lowere reported growth rates in the hunt and Lyons (1986), Lazano-Alvarez et al. (1991), and Phillips et al. (1992) studies. Growth rates reported by Phillips et al. (1992) are higher than in previous studies principally because of the exclusion of lobsters that did not molt from analyses.

Figure 2.2.1 (1). Estimated carapace length (mm) by age (days) after settlement relationships from previous studies in or near Florida.



2.2.2 Tag-based growth determination

Tagging lobsters for growth and migration information has a long history in Florida. Sweat (1968) investigated the feasibility of tagging spiny lobsters by inserting modified sphyrion tags into the extensor muscles of 35 adult spiny lobsters between the posterior edge of the carapace and the first abdominal segment. Of these animals, "… 22 molted retaining the tag. Several of these molted a second time and one lobster has molted a third time still retaining the tag." Little (1972) tagged 2415 spiny lobsters in the Florida Keys and had 118 subsequent recaptures. However, there were only 69 lobsters with size at recapture recorded. The University of Florida researchers tagged 6362 spiny lobsters collected with traps at five sites in the lower Florida Keys from July 1975 through August 1976 and they recovered lobsters from July 1975 to August 1977 (Warner et al. 1977, Gregory and Labisky 1986). Of the tagged lobsters, 2081 lobsters were recaptured at least once. However, not all of the recaptures contained the size at recapture and the date of recapture. Therefore, I used 3026 spiny lobster recaptures from the University of Florida's project. After the University of Florida's project, FWC (then called the Department of Natural Resources) began a similar study collecting lobsters in traps from four stations in the upper and four stations in the middle Keys from April 1978 through March 1979 (Lyons et al. 1981). All together, DNR researchers tagged 19,180 lobsters and 3364 lobsters were recaptured at least once. As with the UF data, not all of the recaptures had the required data and therefore, I used 3372 of the DNR lobster recaptures. The Florida Keys National Marine Sanctuary program created Sanctuary Protected Areas (SPA) and as part of evaluating the effectiveness of the SPAs, FWC tagged spiny lobsters (Cox and Hunt in review) and obtained 330 recaptures. Douglas Gregory tagged spiny lobsters in the lower Keys as part of Sea Grant project and that program had 47 recaptures. Thus, there were 943 more recaptures than the 5901 recaptures that we used in our previous analysis of growth (Muller et al. 1997). To try to limit the analyses to only those animals that molted once while they were at-large, I examined growth increments and the numbers of days at large of those lobsters that showed growth and found that those animals that grew more than 15 mm had been free for more than 85 days; therefore, only lobsters that grew 15 mm or less and were free from 1 to 85 days (6458 recaptures) were included in the modeling.

As was done in Muller et al. (1997), growth was modeled as two processes: the probability of molting during a 30-day period and, for those lobsters that molted, the change in carapace length. The splitting of the growth into the two processes captures the discontinuous nature of molting (Fogarty and Idoine 1988). We combined the data without regard to year because the majority of the recaptures came from 1975-1979. Lyons et al. (1981) recommended considering growth differences of 2 mm or less as uncertainty in measuring the carapace length (CL) and to consider those recaptures as not growing.

Muller et al. (1997) modeled spiny lobster growth as two processes: the probability of molting and, if the animal molted, the change in carapace length in a manner similar to what Fogarty and Idoine (1988) did with the American lobster, *Homerus americanus*. Potential explanatory terms included in the model were sex, season (summer May-Oct and winter Nov-Apr based on water temperatures), area (upper and lower Keys), bay (bay or ocean), days free, and initial carapace length. However, instead of including all the terms with significant Type 3 Sum of Squares like Muller et al. did, I only included terms that reduced the deviance by at least 0.5% from generalized linear models. This approach is the result of discussions of CPUE analyses at the SEDAR Review for yellowtail snapper. The probability of molting was modeled assuming a binomial distribution with a logit link and the growth increment was modeled assuming a log-normal distribution with an identity link. The result of this approach was that the final model captures the dynamics with fewer terms. The reductions in deviance as terms were added are shown in Table 1. After the terms were identified, we fitted a logistic regression to the data to estimate the coefficients and standard errors of the final set of terms used to calculate the probability of molting. The equation for the probability of molting, *P*, was:

$$P = \frac{e^{(1.233 - 1.458\,Season + 0.538\,Sex - 0.0643\,CL + 0.0696\,Days\_free)}}{(1 + e^{(1.233 - 1.458\,Season + 0.538\,Sex - 0.0643\,CL + 0.0696\,Days\_free)})}$$

where values for Season were 0 for Summer and 1 for Winter and the values for Sex were 0 for females and 1 for males.

The terms to include in estimating the growth increment also were identified with generalized linear models with only those recaptures that had growth increments greater than 2 mm (1085 recaptures). The coefficients and their standard errors for estimating the growth increments are shown in Table 1 and the final equation for estimating the change in carapace length,   CL, was:

$$\Delta CL = e^{(2.009 - 0.263\,Season + 0.133\,Sex - 0.00644\,CL + 0.00407\,Days\_free + 0.0674)}$$

where the last expression 0.0674 is half the unexplained mean square from the regression $\square^2/2$) to adjust the predicted change is size for the log-normal distribution. The values for Summer and Sex were the same as calculating the probability. The parameter standard errors were included in Table 2.

To estimate the variability in growth, I generated growth patterns for 1000 lobsters of each sex beginning at one year (April) after settlement at a starting carapace mean length of 46 and a standard deviation of 5.0 mm CL based on the sizes of spiny lobster juveniles that were tagged with coded wires. April was chosen as the starting point based on puerulus settlement patterns observed and Big Pine and Long Key . Each lobster was assigned an initial size by determining a random, normal deviate from a normal distribution. For each month of the 15-year projection, the probability of molting was determined from the coefficients of season, sex, carapace length, and the time at-large in days and their respective standard errors. Prior to calculating the probability of molting, each of the terms in the equation had some uncertainty added with a random, normal deviate times the standard error. A random number was drawn from a uniform distribution from 0 to 1.0 and if the random number was less than or equal to the probability of molting, then the lobster molted. The change in size was calculated using a similar procedure of determining the equation's coefficients by adding back uncertainty with random, normal deviates times the standard errors. The 1000 trajectories of size at month were summarized into five mm length bins and by including all of the sizes for months 1 to 12 into age one and sizes for months 13 to 24 into age two and so on through age 15. The ages were further summarized into 2.5, 25, 50, 75,and 97.5 percentiles (Figure 2). I also noted the month at which each lobster reached legal size (76.2 mm CL) (Figure 3).

As was found before, growth was slower during the winter and females grew more slowly than males. These results reflect that adult female spiny lobsters do not molt when they are carrying eggs or spermatophores while males molt more regularly.

While Muller *et al*. (1997) showed plots for the upper Keys and lower Keys, later stock assessments used the same growth patterns for the Florida Keys which would be similar to these analysis in which area (upper and lower Keys) was not significant. To compare the current results with what has been used earlier, I overlaid the plots of the age-specific medians by sex from this analysis on the earlier medians and there is very little difference (Figure 4).

Table 2.2.2 (1). Identifying parameters that reduce the deviance in the probability of molting by at least 0.5%.

Source		df	Deviance	Dev /df	□ Dev / df	% change	Cum %	Log Like	□ log like	-2 □log like	Prob Ho
Null	Deviance	6457	5847.262	0.9056				-2923.63			
Sex	Deviance	6456	5836.583	0.9041	0.0015	0.2%		-2918.29	5.339	10.679	0.0011
Season	Deviance	6456	5618.284	0.8702	0.0354	3.9%		-2809.14	114.489	228.978	0.0000
Area	Deviance	6456	5787.098	0.8964	0.0092	1.0%		-2893.55	30.082	60.164	0.0000
Bay	Deviance	6456	5847.250	0.9057	-0.0001	0.0%		-2923.63	0.006	0.012	0.9128
Days_free	Deviance	6456	4443.378	0.6883	0.2173	24.0%	24.0%	-2221.69	701.942	1403.884	0.0000
CL	Deviance	6456	5724.770	0.8867	0.0189	2.1%		-2862.39	61.246	122.492	0.0000
Days_free											
Sex	Deviance	6455	4422.727	0.6852	0.0031	0.3%		-2211.36	10.326	20.652	0.0000
Season	Deviance	6455	4313.487	0.6682	0.0201	2.2%		-2156.74	64.946	129.891	0.0000
Area	Deviance	6455	4433.484	0.6868	0.0015	0.2%		-2216.74	4.947	9.894	0.0017
Bay	Deviance	6455	4430.696	0.6864	0.0019	0.2%		-2215.35	6.341	12.682	0.0004
CL	Deviance	6455	4206.944	0.6517	0.0366	4.0%	28.0%	-2103.47	118.217	236.434	0.0000
Days_free and initial CL											
Sex	Deviance	6454	4165.785	0.6455	0.0062	0.7%		-2082.89	20.580	41.159	0.0000
Season	Deviance	6454	4036.566	0.6254	0.0263	2.9%	30.9%	-2018.28	85.189	170.378	0.0000
Area	Deviance	6454	4197.117	0.6503	0.0014	0.2%		-2098.56	4.913	9.827	0.0017
Bay	Deviance	6454	4205.792	0.6517	0.0000	0.0%		-2102.90	0.576	1.152	0.2832
Days_free, initial CL, and Season											
Sex	Deviance	6453	3994.240	0.6190	0.0064	0.7%	31.6%	-1997.12	21.163	42.326	0.0000
Area	Deviance	6453	4012.063	0.6217	0.0037	0.4%		-2006.03	12.252	24.503	0.0000
Bay	Deviance	6453	4036.387	0.6255	-0.0001	0.0%		-2018.19	0.090	0.179	0.6719
Days_free. Initial CL, season, and sex											
Area	Deviance	6452	3969.544	0.6152	0.0038	0.4%		-1984.77	12.348	24.696	0.0000
Bay	Deviance	6452	3993.359	0.6189	0.0001	0.0%		-1996.68	0.441	0.881	0.3479

Table 2.2.2 (1) continued. Identifying the parameters that reduce the deviance in the change in size by at least 0.5%

Source		df	Deviance	Dev /df	□ Dev / df	% change	Cum %	Log Like	□ log like	-2□ log like	Prob Ho
Null	Deviance	1084	170.627	0.1574				-536.001			
Sex	Deviance	1083	167.475	0.1546	0.0028	1.8%		-525.886	10.115	20.23	0.0000
Season	Deviance	1083	162.773	0.1503	0.0071	4.5%		-510.436	25.565	51.13	0.0000
Area	Deviance	1083	168.686	0.1558	0.0016	1.0%		-529.796	6.205	12.41	0.0004
Bay	Deviance	1083	170.538	0.1575	-0.0001	-0.1%		-535.718	0.2825	0.565	0.4523
Days_free	Deviance	1083	161.213	0.1489	0.0085	5.4%	5.4%	-505.213	30.7884	61.5768	0.0000
CL	Deviance	1083	166.828	0.1540	0.0034	2.2%		-523.787	12.2144	24.4288	0.0000
Days_free											
Sex	Deviance	1082	157.447	0.1455	0.0034	2.2%		-492.39	12.8226	25.6452	0.0000
Season	Deviance	1082	154.686	0.1430	0.0059	3.7%	9.1%	-482.793	22.4192	44.8384	0.0000
Area	Deviance	1082	160.847	0.1487	0.0002	0.1%		-503.979	1.2331	2.4662	0.1163
Bay	Deviance	1082	161.062	0.1489	0.0000	0.0%		-504.705	0.5075	1.015	0.3137
CL	Deviance	1082	157.067	0.1452	0.0037	2.4%		-491.078	14.1347	28.2694	0.0000
Days_free and season											
Sex	Deviance	1081	151.078	0.1398	0.0032	2.0%		-469.987	21.0913	42.1826	0.0000
Area	Deviance	1081	154.429	0.1429	0.0001	0.1%		-481.889	9.1886	18.3772	0.0000
Bay	Deviance	1081	154.663	0.1431	-0.0001	-0.1%		-482.71	8.3676	16.7352	0.0000
CL	Deviance	1081	150.358	0.1391	0.0039	2.5%	11.6%	-467.397	23.6807	47.3614	0.0000
Season, days_free, and sex											
Sex	Deviance	1080	145.678	0.1349	0.0042	2.7%	14.3%	-450.244	31.6455	63.291	0.0000
Area	Deviance	1080	150.334	0.1392	-0.0001	-0.1%		-467.309	14.58	29.16	0.0000
Bay	Deviance	1080	150.313	0.1392	-0.0001	-0.1%		-467.235	14.6545	29.309	0.0000
Season, days_free, sex and initial CL											
Area	Deviance	1079	145.644	0.1350	-0.0001	-0.1%		-450.115	0.1285	0.257	0.6122
Bay	Deviance	1079	145.512	0.1349	0.0000	0.0%		-449.624	0.6197	1.2394	0.2656

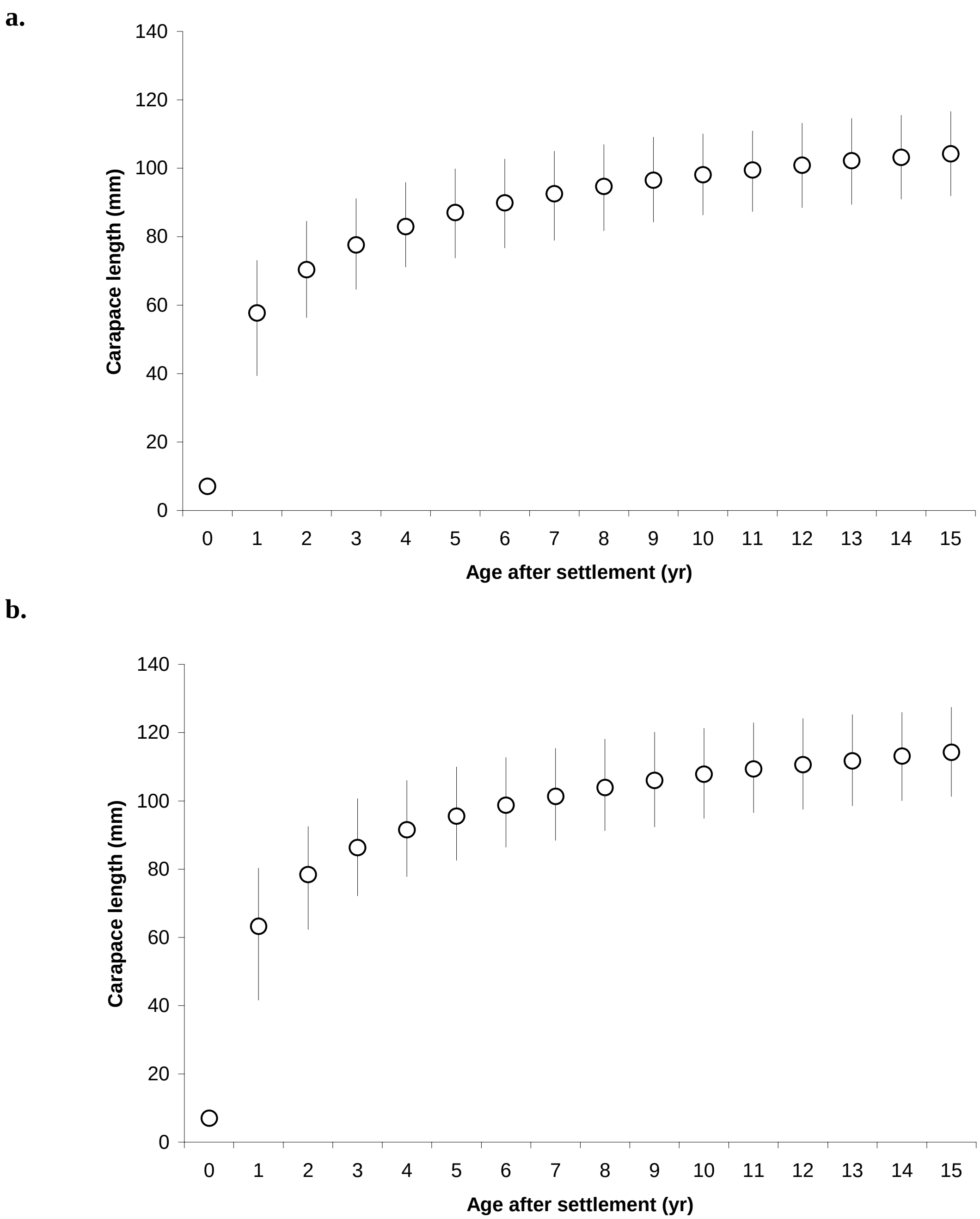


Figure 2.2.2 (2). Estimated carapace lengths by age after settlement by sex (a. females and b. males). Vertical lines are the 95% confidence intervals and the circles are the median lengths based on 1000 growth trajectories.

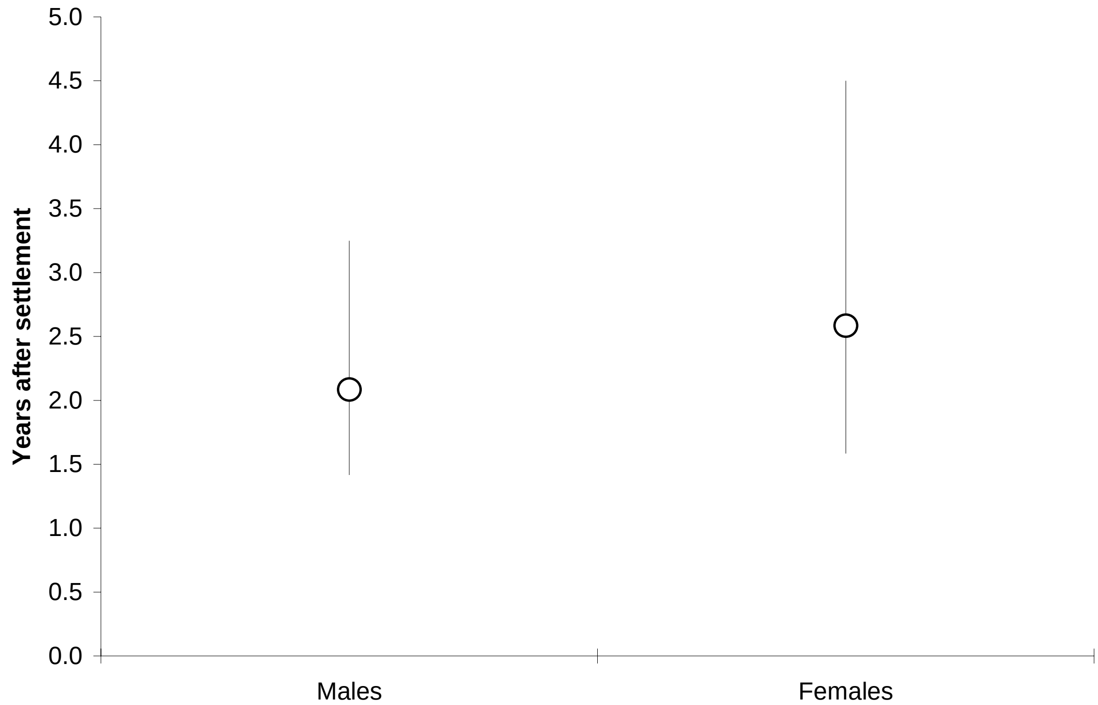
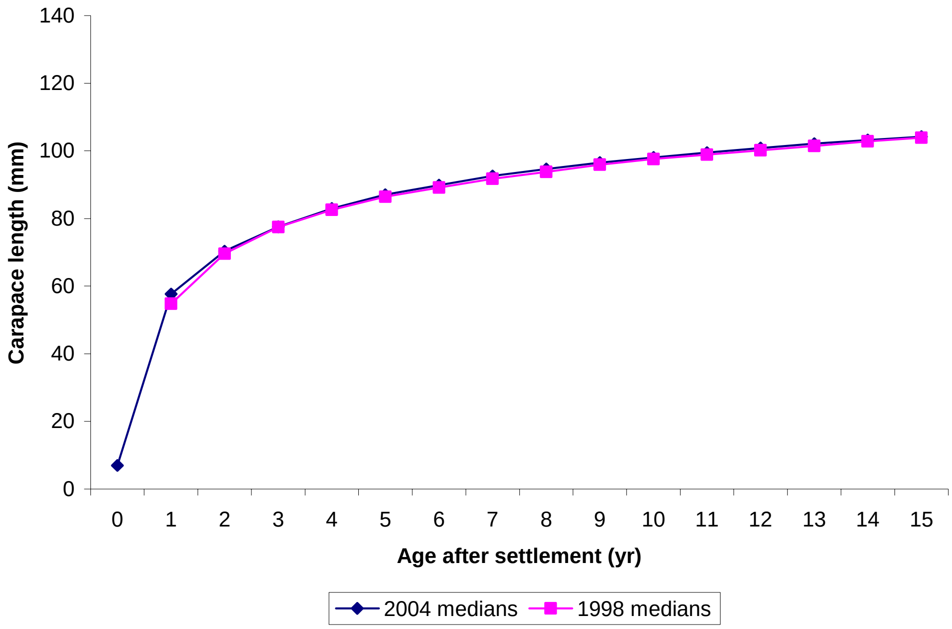


Figure 2.2.2 (3). Estimated time in months to reach legal size (76.2 mm CL) by sex. Vertical lines are the 95% confidence intervals and the circles are the median lengths based on 1000 growth trajectories.

a.



b.

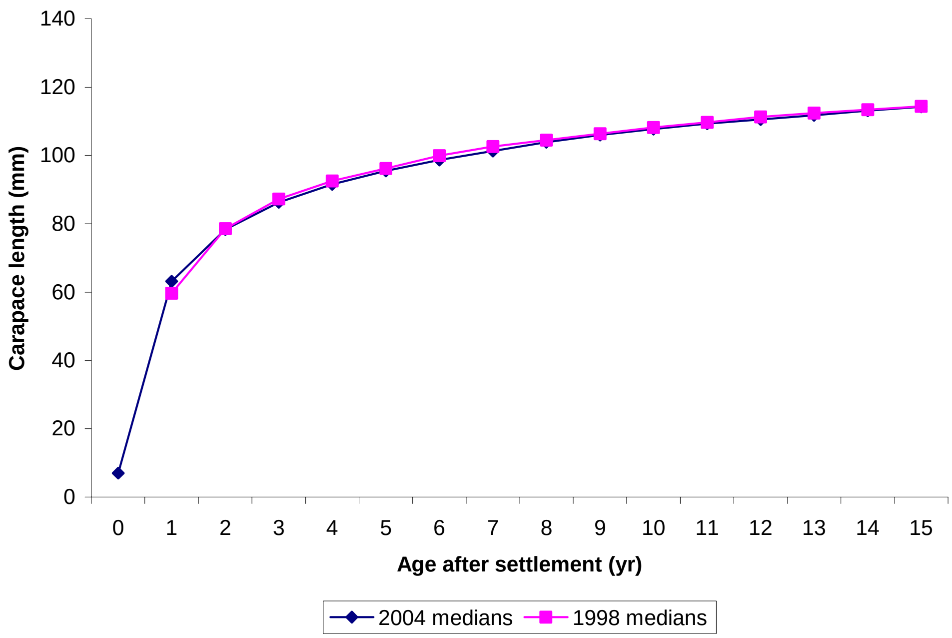


Figure 2.2.2 (4). Comparison of medians from the 1998 stock assessment and from this analysis.

Table 2.2.2 (2). The parameter estimates and their standard errors that were used to model growth.

Process	Parameter	Estimate	Standard errors
Probability of molting	Intercept	1.2332	0.2769
	Season	-1.4583	0.1244
	Sex	0.5378	0.0833
	Carapace length	-0.0643	0.00394
	Days free	0.0696	0.00215
Change in size	Intercept	2.008631	0.07458
	Season	-0.26268	0.037696
	Sex	0.13285	0.022554
	Carapace length	-0.00644	0.001017
	Days free	0.004069	0.000495
	Mean square	0.1348873	

2.2.3 Lipofuscin-based growth determination

The determination of growth in crustaceans using the accumulation of lipofuscin has been relatively successful (Sheehy *et al*. 1990) and has been previously applied to three other species of lobster, *Homarus gammarus* (Sheehy *et al*. 1996), *Homarus americanus* (Whale *et al*. 1996), and *Panulirus cygnus* (Sheehy *et al*. 1998). Lipofuscin accumulates in cells at varying rates dependent on temperature, food availability, and longevity and is thus a measure of physiological aging rather than chronological aging.

We developed growth curves for male and female *Panulirus argus* from the Keys and from the Dry Tortugas. We collected 75 male and 75 female lobsters from the middle and upper Florida Keys and 50 male and 50 female lobsters from the Dry Tortugas. We then measured the amount of lipofuscin in a group of neurons associated with cluster A in the optic nerve. From these samples we estimated the age of each lobster based on the relationship between age and lipofuscin accumulation for known-age lobsters raised in the laboratory.

Lobsters of known age were raised in the laboratory from pueruli for up to 4 years. Laboratory temperature was maintained within 1 C^o of the temperature in Florida Bay for the first year of each lobsters life and at the temperature of Sombrero Reef for the remaining time in the lab. A combination of frozen shrimp, fish, and squid, live snails, shrimp, and crabs, and fresh fish was provided *ad libatum* daily. These conditions were utilized to simulate natural growth rates as closely as possible in a laboratory setting.

We developed a power function to describe the lipofuscin-age relationship for the known-age lobsters raised in the laboratory:

$$\text{Age} = b_0(\text{Lipofuscin}^{b_1})$$

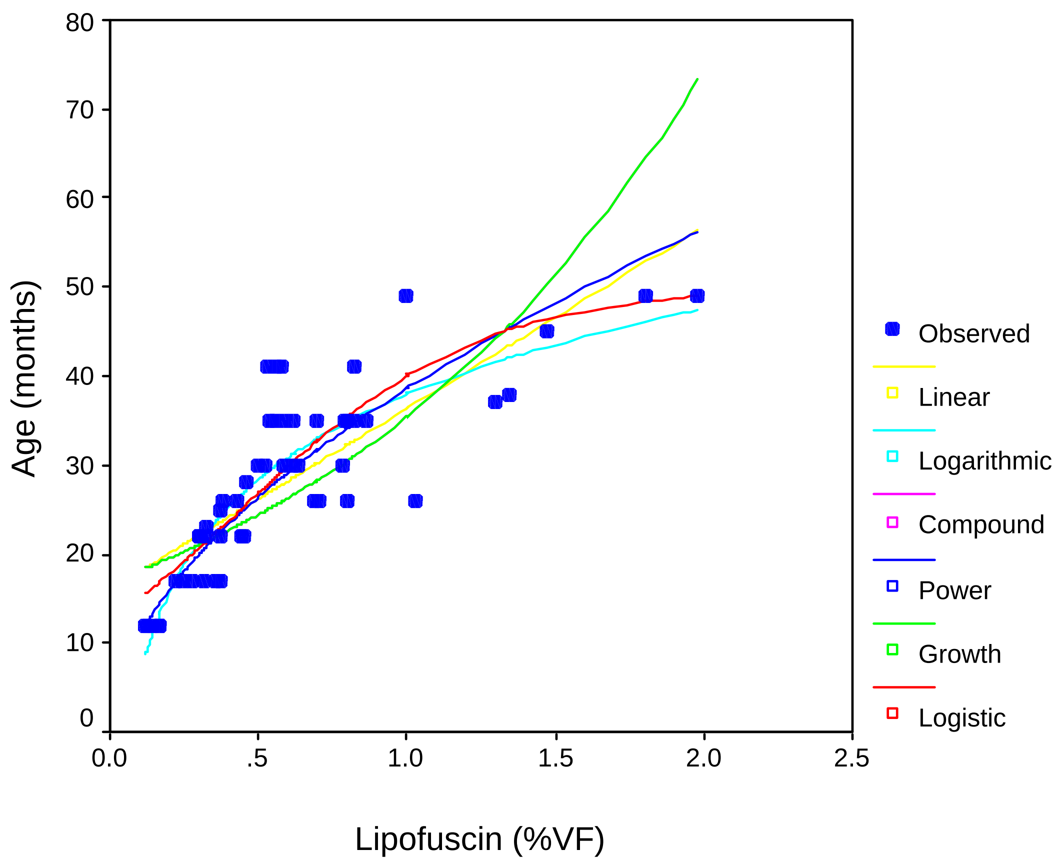
where age = months and lipofuscin = %VF, (r^2=0.799).

The power function provided the best fit (r^2) for the relationship between lipofuscin and age in the laboratory (Table 1) and also minimized the residuals for lobsters younger than 35 months, which included lipofuscin concentrations for most of the lobsters observed in the fishery. The logistic and logarithmic equations minimized residuals at higher values but did not fit well at the low lipofuscin values that were commonly observed in the fishery. The logarithmic equation underestimated age at low lipofuscin concentrations, and the logistic equation overestimated age at low lipofuscin values (Figure 1).

Table 2.2.3 (1). Potential equations describing the relationship between lipofuscin and age for laboratory reared *Panulirus argus*.

Equation Type	r^2	d.f.	Equation
Linear	0.644	49	$Y=15.9937 + 20.4037t$
Logarithmic	0.760	49	$Y= 37.9543 + 13.8253 ln(t)$
Compound	0.573	49	$Y = 16.8382(2.1034)^t$
Power	0.799	49	$Y = 38.6278(t^{0.5476})$
Growth	0.573	49	$Y = e(^{2.8236 + 0.7436t})$
Logistic	0.707	49	$Y = 1 / (1/u + 0.0597(0.0837^t))$ upper bound (u) set at 50

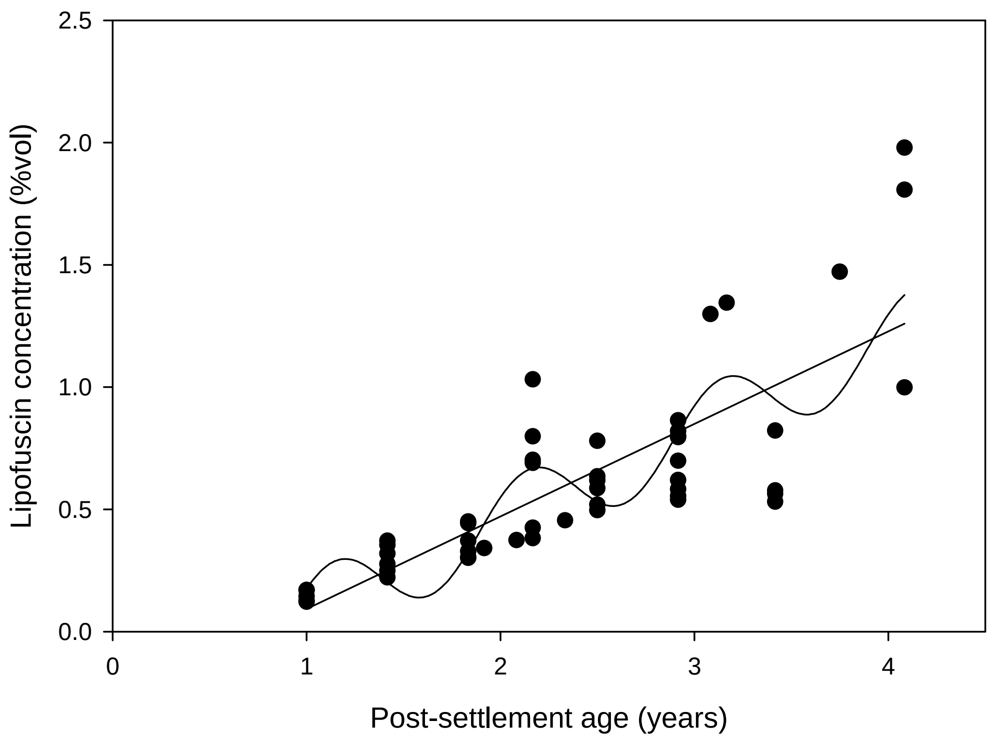
Figure 2.2.3 (1) Lipofuscin concentration for laboratory-reared lobsters *Panulirus argus* and potential equations describing the relationship between lipofuscin and age.



There was no difference between the amount of lipofuscin observed in male and female lobsters from a select group of lobsters that were raised in the same aquaria for 35 months (ANCOVA with age as covariate, p = 0.91). Differential survival of male and female lobsters over 35 months age precluded use of this test for lobsters of all ages. Lobsters over 35 months age were exposed to the lethal virus PaV1 (Shields and Behringer, 2004) killing all but 2 females and 7 males.

Lobsters raised in the laboratory showed signs of differential rates of lipofuscin deposition at different temperatures and may have a mechanism to excise lipofuscin from cells. Although this does no appear to have affected the amount of lipofuscin present in lobsters up to four years old, The relationship between lipofuscin accumulation and age for lobsters over 4-years old would need to be verified (Figure 2).

Figure 2.2.3 (2). A seasonalized linear model describing the effects of season on lipofuscin deposition in *P. argus*.



Separate von Bertalanffy equations were calculated for male and female *Panulirus argus* in the Florida Keys and Dry Tortugas using FiSAT II (Table 3). The amount of lipofuscin observed in each lobster was used to estimate age using the power function developed in the laboratory (Table 1). Growth curves for lobsters in the Dry Tortugas are much higher than reported in previous studies (Figure 3). Although we believe our estimation of lobster growth differences between the Keys and Dry Tortugas are accurate, the accumulation of lipofuscin could be affected by a diet. A diet high in antioxidants would reduce the accumulation of lipofuscin and lower the physiologic age of lobster in our study. If lobsters in the Dry Tortugas had a diet substantially higher in antioxidants than lobsters in the Keys, their physiological age would appear lower than that of other lobsters. Growth curves for male and female lobsters from the Keys are similar to those reported by Phillips *et al*. (1992) in Cuba.

Table 2.2.3 (2). Von Bertalanffy parameters for male and female lobsters from the Florida Keys and Dry Tortugas.

Sex and Location	Parameter	Value	S.E. of estimate	C.V. of estimate
Males in Keys	L_{inf}	128.22	36.6486	.2858
	K	.60	.4442	.7433
Females in Keys	L_{inf}	107.91	16.9345	.1569
	K	.78	.4280	.5453
Males in Tortugas	L_{inf}	209.14	52.8560	.2527
	K	.47	.3155	.6696
Females in Tortugas	L_{inf}	152.61	20.6769	.1355
	K	.74	.4635	.6268

Figure 2.2.3 (3). Von Bertalanffy curves for length at age for male and female lobsters from the Florida Keys and Dry Tortugas.

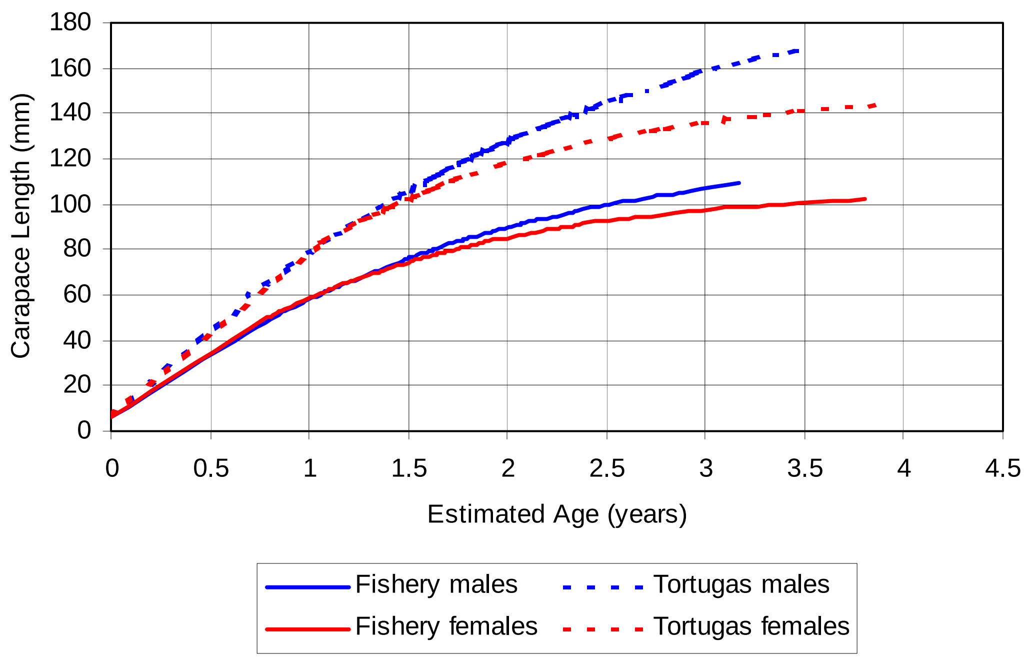


Table 2.2.3 (3). Von Bertalanaffy growth parameter estimates (FAO 2001), Γ = males and E = females

Zone	Sex	Method	K	L_∞	ϕ'	T_0	References
Bahamas	Γ	Unknown	0.26	190	3.93[1]		Waugh (1980)
	E		0.23	190			
Bermuda	Γ	Unknown	0.18	204	3.83[1]	0.82	Evans (1988)
	E		0.15	192		1.0	
Brazil	Γ	Modal Progression Analysis	0.34	141	4.11[1]		Santos *et al.* (1964)
	E		0.38	148			
Brazil	Γ	ELEFAN	0.229	257	4,19		Ivo (1996)
	E		0.236	233			
Brazil	Γ	SLCA	0.26	207	3.97		González Cano and Rocha (1995)
	E		0.18	162			
Cuba, SW	Γ	Bhattacharya	0.22	169	3.79	-0.70	Cruz, *et al.* (1981)
	E		0.31	139		0.08	
Cuba, SW	Γ+E	Bhattacharya	0.16	174	3.68	0.32	Buesa (1972)
Cuba, SW	Γ	ELEFAN	0.29	250	4.19		Báez, *et al.* (1991)
	E		0.31	209			
Cuba, SW	Γ	Tagging	0.27	250	4.15[1]		Phillips, *et al.* (1992)
	E		0.39	171			
Cuba, SW	Γ	ELEFAN	0.31	190	3.95[1]		León, *et al.* (1994)
	E		0.24	174			
Cuba, SW	Γ	Fournier	0.21	178	3.81[1]		Báez, *et al.* (1994)
	E		0.21	171			
Cuba, SW	Γ	SLCA	0.24	184	3.85[1]	0.45	León, *et al.* (1995)
	E		0.18	155		0.37	
Cuba, SE	Γ		0.22	186	3.88[1]	0.44	
	E		0.22	156		0.41	
Cuba, NE	Γ		0.23	185	3.83[1]	0.44	
	E		0.19	153		0.38	
Cuba, NW	Γ		0.22	175	3.85[1]	0.43	
	E		0.22	166		0.42	
Cuba, all areas	Γ		0.23	185	3.86[1]	0.44	
	E		0.19	155		0.37	
Florida, USA	Γ+E	Tagging	0.34	190	4.09[1]		Davis (1977)
Florida, USA	Γ+E	Tagging	0.25	190	3.95[1]		Warner *et al.* (1977)
Jamaica	Γ+E	MPA	0.22	192	3.89[1]		Munro (1974)
Martinique	Γ	Unknown	0.25	190	3.93[1]		Clairovin (1980)
	E		0.23	188			
Mexico, Isla Mujeres	Γ	SLCA	0.24	198	3.95[1]	0.41	Gonzalez-Cano (1991)
	E		0.22	165		0.86	
Mexico, Isla Mujeres	Γ	SLCA	0.25	217	4.04		González Cano and Rocha (1995)
	E		0.22	146			
Mexico, Isla	Γ	SLCA	0.30	142	3.72[1]		Arce (1990)
Mujeres	E		0.30	122			
Mexico, Bahía de la Ascención	Γ	Fabens	0.20	257	4.09[1]		Lozano-Alvarez *et al.* (1991a)
	E		0.25	215			
Nicaragua	Γ	ELEFAN	0.23	169	3.89		Castaño and Cadima (1993)
	E		0.40	160			
	Γ+E		0.3	161			
Virgin Islands, USA	Γ	Tagging	0.44	153	3.88[1]		Olsen and Koblic (1975)
	E		0.32	133			
Sub-regional	Γ	ELEFAN	0.23	180	3.97[1]	-0.84	Estimates made during the 1997 working group session.
Nicaragua, Jamaica, Colombia	E		0.21	163		-0.95	
	Γ+E		0.26	190		-0.68	

3.0 Fishery Descriptions and Data Sources

3.1 Commercial Fishery

3.1.1 Fishery Descriptions and Data Sources Commercial Fishery

Overview

Various authors have documented the development of Florida's spiny lobster commercial fishery. Several annual reports of the Commissioner for Fisheries contained information on landings from either the South Atlantic states or the Gulf states and from these we were able to extend the landings back to 1897. Crawford and De Smidt (1922) noted that the fishery started as a bait fishery for hook-and-line fishing in the late 1800s and noted that Key West had landings of 53,000 pounds in 1908 with a value of $3,600. Lobster landings increased after the railroad reached the Keys in 1912 providing access to expanded markets. Cast nets, gill nets, and haul seines were the commonly used gears. Dawson and Idyll (1951) noted that the wooden slate trap was introduced in the 1920s and eventually became the dominant gear. They also reconstructed historical landings from 1925 to 1950. Two other milestones in the developing spiny lobster fishery were the lowering of the minimum size in 1965 which opened up the Florida Bay nursery area to fishing and the use of sub-legal sized lobsters as attractants beginning in 1977.

A common theme in these descriptions of historical landings was that these numbers should be considered as minimal levels because recorded landings were the weight reported by dealers but fishers were not required to sell the catches to dealers and dealers in Florida were not required to report until the implementation of the trip ticket program in 1984. Also missing from these landings were the lobsters that were used for bait by the fishers and artisanal harvest.

Commercial Landings

United States landings by calendar year were extracted from a variety of sources. Landings from 1897 through 1938 came mostly from the Reports of the Commissioner for Fisheries (U.S. Department of Commerce) but those from 1934-1938 by coast were taken from the Spiny Lobster Fishery Management Plan (GMFMC and SAFMC 1982), landings from 1939 through 1949 were taken from the Florida Board of Conservation Biennial Reports, and the commercial landings from 1950 through 2003 by state came from NOAA Fisheries' commercial statistics website:

http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html

The Florida Board of Conservation Annual Reports only reported statewide landings by species' totals and did not report the landings by coast until 1950. Monthly landings from 1978 through 1985 by county came from NOAA Fisheries' Southeast Science Center's General Canvass database. As of 1984, fishers in Florida were required to sell their fish or invertebrates only to licensed wholesale dealers and those dealers were required to complete a trip ticket for each purchase. Trip tickets contain several relevant pieces of information for stock assessment including the fishers license number, the date of the sale, the wholesale dealer, the gear used on the trip beginning in 1991, depth fished, in the case of spiny lobster, the number of traps used on the trip, the soak time of those traps, the species landed, the volume landed, and the price. Florida's Marine Information Resources System (MRIS) provided information on commercial landings by month and county from 1986 through March 2004 on a per trip basis and included all trip tickets that were received by FWC by 26 October 2004 (edited batch 854). There were no unedited tickets for spiny lobster in any of the pending batches as of 27 December 2004 and, although some late tickets may still turn up, these data through 2003-04 are considered complete.

As mentioned in the Overview (Section 3.1.1), when Florida's legislature reduced the three-inch minimum size in 1965, the fishery expanded into Florida Bay and also onto the Bahama Banks. Figure 1a shows the anomalous increase in Florida's Atlantic coast landings from 1966 until 1975 when the Bahamian government closed their waters to U.S. fishing. Landings at that time (1966-1975) were not reported by area fished and we had to account for those landings that came from the Bahamas with statistical methods. Milon et al. (1999) estimated Florida's Atlantic coast landings with the number of traps used on the Atlantic coast and then applied the pounds per trap from the Gulf coast to those traps. However, when those corrections from Milon et al.'s Appendix B (the difference between Nominal and Bahamian Corrected) were applied to the Atlantic landings that were obtained from the NOAA Fisheries website, the "corrected landings" were negative in 1971 and 1972. Therefore as an alternative approach to adjusting for the Bahamian landings recorded as coming from Florida, we calculated a regression of the Atlantic landings to Gulf landings from 1950 to 1965 when the minimum size was reduced and from 1975 through 1992 on time. Florida's Trap Reduction Program implemented in 1993 precluded using information from 1993 and later. The semi-log regression of Florida's Atlantic landings on those from the Gulf was significant ($F = 65.2$, $df = 1, 30$, $P < 0.05$) but the intercept term was not significant ($t = 1.34$, $df = 30$, $P = 0.19$) so we recalculated the slope with a no-intercept regression ($t = -16.34$, $df = 30$, $P < 0.05$). The corrected landings for the Atlantic coast are shown in Figure 1b and are included in Table 1.Commercial landings for spiny lobster in the U. S. from 1897 through 2003 are shown in Figure 2 and in Table 1. The spiny lobster fishery started in Key West in the Florida Keys in the 1800s as a bait fishery and for some local consumption. Reported landings did not exceed a million pounds until 1941. The Reports to the Board of Conservation did not make any explanation of the sharp increase in landings reported in 1942 and in the late 1940s. Landings made a major increase after 1965 and have varied without trend after 1970; however, landings in 2001 were the lowest in forty years. There were some landings from other states during the 1960s and early 1970s but these amounts were low and other than 1140 pounds in 1987, commercial landings of spiny lobsters have been from Florida for the last couple of decades and so we focus on Florida.

Because the gear used on each trip was not recorded on trip tickets until the latter part of 1991, the proportion of landings by gear from 1978 through 1992 were taken from NOAA Fisheries' General Canvass and from MRIS thereafter. However, gear was not available on a monthly basis in the General Canvass and therefore the breakdown by gear had to be tallied on a calendar year basis even though the fishery operates on a fishing year basis. Annual landings by gear are shown in Table 2. After the Trap Reduction Program was implemented in 1993, divers began to produce a larger proportion of the landings as illustrated for 2003 in Figure 3. Due to the seasonal closure in the fishery, the more common way of referring to landings is by fishing year which is from August 6 through March 31 of the following year. Landings by fishing year and region are shown in Table 3. The Florida Keys account for an average of 90% of the landings. The season with the highest landings was 1989-90 with 7.8 million pounds and the 2001-02 season had the lowest with 3.1 million pounds. If we just consider the 1993-94 and later seasons (seasons with the Trap Reduction Program), the 1993-97 seasons in the Florida Keys averaged 1.8 million pounds more than the five most recent seasons. The trap fishery declined an average of 2.0 million pounds per season while the diver fishery increased their harvest by 0.18 million pounds.

Commercial catch rates in terms of pounds per trip were calculated in SAS with generalized linear models (PROC GENMOD) that used gamma distributions with an inverse link. The gamma distribution, with its shape parameter, is flexible. To keep from overspecifying the model, variables were included in the model if the variable accounted for at least 0.5% of the mean deviance (deviance/degrees of freedom). Three sets of catch rates were calculated: overall using trip information from 1985-86 through 2003-04 fishing years, trap catch rates from 1992-93 and later, and diver catch rates again from 1992-93 and later fishing years. To ensure comparability, the trip data were subset to Southeast Florida and the Florida Keys and one-day trips only. Confidence intervals were empirically determined as the 25^{th}, 500^{th}, and 975^{th} values from Monte Carlo simulations of 1000 random values.

There were 502,216 trip tickets that met the criteria (one-day trips from Southeast Florida and the Florida Keys). Potential explanatory variables included fishing year, region, and month. Month explained almost 11% of the deviance and fishing year explained another 2% (Table 4). Although the catch rates have been variable, they did not show a trend (test for slope different than zero, $t = 1.01$, $d.f. = 17$, $P = 0.33$). The highest overall catch rate occurred in 1988-89 and the lowest occurred in 1990-91 (Figure 4a, Table 5). The catch rate falls off as the season progresses (Figure 4b).

There were 182,546 trip tickets from Southeast Florida and the Florida Keys that indicated one day fishing, with 1 to 600 traps, and soak times of 1 to 30 days. Potential explanatory variables considered fishing year, region, month, number of traps, and soak time. However, when number of traps was included initially in the model, the model was unable to converge so the number of traps was converted to 50-trap categories. The trap category explained 33% of the deviance in pounds landed, month explained another 7.8%, and fishing year explained another 2%. While neither region nor soak time explained the minimum of 0.5%, the model explained 42% of the variability. As expected because of traps being the dominant gear, the pattern in trap catch rates (Figure 5a) was similar to the overall pattern in catch rates. The trap catch rates also decreased as the season progresses (Figure 5b). There were 33,391 trip tickets that specified one days diving in Southeast Florida or the Florida Keys. For divers, month explained 15% of the deviance and fishing year explained another 4%. Region was not significant in estimating any of these catch rates. While the trap fishery varied without trend, the divers' catch rates increased until the 1999-2000 fishing year and then leveled off with dips in 2001-02 and 2003-04 (Figure 6b). The seasonal pattern was different with divers because they take the majority of the their landings in coming from August (67%) (Figure 6b).

To provide a context for evaluating the U.S. fishery, we provide landings by other countries in the Western Atlantic. Spiny lobster landings from 1950 to 2001 (the most recent year) by country for the western Atlantic were obtained from the United Nations Food and Agriculture Organization's (FAO) database (FishStat Plus version 2.3, Figure 7). For consistency, corrected landings for Florida's Atlantic Coast (described below) were used in place of the FAO reported landings. Landings from the U.S. were only from the continental U.S. and did not include those from the U.S. Virgin Islands. In 2001, spiny lobster landings from the Western Atlantic including Brazil were 34,000 metric tons. The 2001 landings by major producing countries are shown in Figure 8. Cuba reported the highest landings, followed by the Bahamas, and the United States reported the fifth highest landings in the region.

Table 3.1.1 (1). Annual landings and the numbers of traps statewide by calendar year and coast including corrected values for the Atlantic coast.

Year	Atlantic	Gulf	Statewide
1897			157,500
1898			
1899			
1900			
1901			
1902			55,664
1903			
1904			
1905			
1906			
1907			
1908			53,000
1909			
1910			
1911			
1912			
1913			
1914			
1915			
1916			
1917			
1918	23,503	322,015	345,518
1919			
1920			
1921			
1922			300,000
1923	156,200	321,010	477,210
1924			
1925			
1926			
1927	260,536	130,717	391,253
1928	367,106	197,056	564,162
1929	220,766	192,500	413,266
1930	108,309	180,000	288,309
1931	303,800	152,107	455,907
1932	347,207	98,340	445,547

Year	Atlantic	Corrected Atlantic	Gulf	Statewide	Number of Traps
1933					
1934	183,000		168,000	351,300	
1935					
1936	210,600		116,000	326,600	
1937	225,000		68,000	292,000	
1938	265,000		63,000	328,000	
1939				405,296	
1940				399,837	
1941				2,087,191	
1942				1,673,065	
1943				1,910,766	
1944				1,176,044	
1945				793,693	
1946				1,585,510	
1947				4,890,900	
1948				3,953,561	
1949				3,581,043	
1950	931,500		628,200	1,559,700	
1951	2,020,200		1,077,200	3,097,400	
1952	655,700		956,700	1,612,400	4,500
1953	1,121,200		874,200	1,995,400	6,500
1954	1,223,300		724,000	1,947,300	11,690
1955	1,079,400		1,216,000	2,295,400	12,700
1956	798,800		2,314,200	3,113,000	16,775
1957	651,300		3,388,500	4,039,800	21,720
1958	622,800		2,331,500	2,954,300	23,221
1959	543,000		2,636,600	3,179,600	33,612
1960	719,400		2,129,100	2,848,500	54,640
1961	702,000		2,101,400	2,803,400	38,990
1962	704,600		2,434,600	3,139,200	58,250
1963	814,600		2,770,600	3,585,200	60,050
1964	785,700		2,845,400	3,631,100	73,553
1965	1,364,000	1,695,219	4,385,100	6,080,319	89,700
1966	1,686,100	1,329,526	3,664,100	4,993,626	74,550
1967	1,676,600	932,153	2,737,000	3,669,153	91,800
1968	3,238,300	1,253,344	3,920,800	5,174,144	98,500

Year	Atlantic	Corrected Atlantic	Gulf	Statewide	Number of Traps
1969	3,810,800	1,395,964	4,652,600	6,048,564	96,955
1970	3,050,800	1,929,568	7,064,400	8,993,968	150,050
1971	3,417,900	1,265,634	5,294,200	6,559,834	147,037
1972	6,432,600	1,277,545	5,379,300	6,656,845	174,490
1973	5,621,600	1,292,444	5,572,600	6,865,044	171,590
1974	4,147,200	1,472,168	6,736,200	8,208,368	227,250
1975	2,319,300	1,044,042	5,089,200	6,133,242	428,250
1976	987,300		4,358,300	5,345,600	305,000
1977	1,500,700		4,843,400	6,344,100	408,000
1978	890,519		4,711,384	5,601,903	529,200
1979	840,386		6,987,883	7,828,269	593,000
1980	998,516		5,696,326	6,694,842	605,000
1981	879,537		5,014,468	5,894,005	622,000
1982	857,171		5,639,633	6,496,804	542,000
1983	653,746		3,663,254	4,317,000	555,000
1984	205,264		6,046,653	6,251,917	675,000
1985	294,883		5,444,510	5,739,393	564,000
1986	621,350		4,385,354	5,006,704	576,000
1987	569,386		5,514,261	6,083,647	777,000
1988	514,070		5,794,360	6,308,430	787,000
1989	516,266		7,156,893	7,673,159	916,000
1990	563,769		5,423,195	5,986,964	876,000
1991	967,625		6,055,184	7,022,809	939,000
1992	481,510		4,004,911	4,486,421	831,000
1993	884,021		4,494,786	5,378,807	704,615
1994	809,572		6,294,632	7,104,204	639,164
1995	695,627		6,328,311	7,023,938	582,985
1996	672,472		7,196,075	7,868,547	594,384
1997	616,805		6,490,713	7,107,518	597,656
1998	537,642		5,291,490	5,829,132	535,492
1999	704,169		6,825,436	7,529,605	540,000
2000	588,929		5,183,741	5,772,670	524,704
2001	448,915		2,962,338	3,411,253	540,080
2002	413,925		4,070,673	4,484,598	507,152
2003	394,528		3,875,303	4,269,831	496,661

Table 3.1.1 (2). Annual landings and percent composition by gear. The percentage by gear types did not include the landings with unknown gears. Gear data from NMFS website for years 1950-1992 and Florida Trip Tickets from 1993-2004.

	Pounds					Percent			
Year	Traps	Divers	Other	Unknown	Total	Traps	Diving	Other	Total
1950	1,558,800		900		1,559,700	99.9%	0.0%	0.1%	100.0%
1951	3,091,500		5,900		3,097,400	99.8%	0.0%	0.2%	100.0%
1952	1,612,400				1,612,400	100.0%	0.0%	0.0%	100.0%
1953	1,995,000		400		1,995,400	100.0%	0.0%	0.0%	100.0%
1954	1,945,700		1,600		1,947,300	99.9%	0.0%	0.1%	100.0%
1955	2,252,900		42,500		2,295,400	98.1%	0.0%	1.9%	100.0%
1956	3,099,800		13,200		3,113,000	99.6%	0.0%	0.4%	100.0%
1957	3,994,700		45,100		4,039,800	98.9%	0.0%	1.1%	100.0%
1958	2,915,600		38,700		2,954,300	98.7%	0.0%	1.3%	100.0%
1959	3,145,800		33,800		3,179,600	98.9%	0.0%	1.1%	100.0%
1960	2,815,000	500	33,000		2,848,500	98.8%	0.0%	1.2%	100.0%
1961	2,772,800		30,600		2,803,400	98.9%	0.0%	1.1%	100.0%
1962	3,126,600		12,600		3,139,200	99.6%	0.0%	0.4%	100.0%
1963	3,563,200		22,000		3,585,200	99.4%	0.0%	0.6%	100.0%
1964	3,585,100		46,000		3,631,100	98.7%	0.0%	1.3%	100.0%
1965	5,457,000		292,100		5,749,100	94.9%	0.0%	5.1%	100.0%
1966	5,271,300		78,900		5,350,200	98.5%	0.0%	1.5%	100.0%
1967	4,329,300	3,000	81,300		4,413,600	98.1%	0.1%	1.8%	100.0%
1968	7,051,600	1,200	106,300		7,159,100	98.5%	0.0%	1.5%	100.0%
1969	8,345,600		117,800		8,463,400	98.6%	0.0%	1.4%	100.0%
1970	10,030,600	6,900	77,700		10,115,200	99.2%	0.1%	0.8%	100.0%
1971	8,655,100	9,800	47,200		8,712,100	99.3%	0.1%	0.5%	100.0%
1972	11,764,700	6,800	40,400		11,811,900	99.6%	0.1%	0.3%	100.0%
1973	10,995,000	154,100	45,100		11,194,200	98.2%	1.4%	0.4%	100.0%
1974	10,433,200	197,800	252,400		10,883,400	95.9%	1.8%	2.3%	100.0%
1975	7,195,400	122,200	90,900		7,408,500	97.1%	1.6%	1.2%	100.0%
1976	5,255,000	58,700	31,900		5,345,600	98.3%	1.1%	0.6%	100.0%
1977	6,109,700	168,400	66,000		6,344,100	96.3%	2.7%	1.0%	100.0%
1978	5,353,200	155,300	96,800		5,605,300	95.5%	2.8%	1.7%	100.0%
1979	7,548,200	138,800	141,300		7,828,300	96.4%	1.8%	1.8%	100.0%
1980	6,313,388	211,921	170,223		6,695,532	94.3%	3.2%	2.5%	100.0%
1981	5,552,477	185,220	156,402		5,894,099	94.2%	3.1%	2.7%	100.0%
1982	6,113,238	214,649	168,982		6,496,869	94.1%	3.3%	2.6%	100.0%
1983	4,048,725	134,908	133,455		4,317,088	93.8%	3.1%	3.1%	100.0%
1984	5,996,465	190,418	65,034		6,251,917	95.9%	3.0%	1.0%	100.0%
1985	5,523,085	115,603	100,705		5,739,393	96.2%	2.0%	1.8%	100.0%
1986	4,889,913	94,818	22,080	44,672	5,051,483	97.7%	1.9%	0.4%	100.0%
1987	5,909,493	140,131	34,472	18,346	6,102,442	97.1%	2.3%	0.6%	100.0%
1988	6,089,987	161,082	60,005	1,708	6,312,782	96.5%	2.6%	1.0%	100.0%
1989	7,494,290	108,167	72,253	10,898	7,685,608	97.6%	1.4%	0.9%	100.0%
1990	5,800,167	147,092	39,418	796	5,987,473	96.9%	2.5%	0.7%	100.0%
1991	6,701,199	225,873	70,746	25,046	7,022,864	95.8%	3.2%	1.0%	100.0%
1992	4,260,161	185,366	41,187	3	4,486,717	95.0%	4.1%	0.9%	100.0%

Table 3.1.1 (2) continued. Annual landings and percent composition by gear. The percentage by gear types did not include the landings with unknown gears. Gear data from NMFS website for years 1950-1992 and Florida Trip Tickets from 1993-2004.

	Pounds					Percent			
Year	Traps	Divers	Other	Unknown	Total	Traps	Diving	Other	Total
1993	4,881,479	161,466	18,532	315,806	5,377,283	96.4%	3.2%	0.4%	100.0%
1994	6,607,294	261,248	29,362	189,453	7,087,357	95.8%	3.8%	0.4%	100.0%
1995	6,524,754	305,401	24,659	146,847	7,001,661	95.2%	4.5%	0.4%	100.0%
1996	7,330,766	323,010	44,388	167,506	7,865,670	95.2%	4.2%	0.6%	100.0%
1997	6,544,955	410,826	107,229	44,500	7,107,510	92.7%	5.8%	1.5%	100.0%
1998	5,238,948	338,054	225,639	28,766	5,831,407	90.3%	5.8%	3.9%	100.0%
1999	6,809,604	542,708	194,408	31,602	7,578,322	90.2%	7.2%	2.6%	100.0%
2000	4,859,048	671,093	232,978	348	5,763,467	84.3%	11.6%	4.0%	100.0%
2001	2,922,694	443,084	39,610	.	3,405,388	85.8%	13.0%	1.2%	100.0%
2002	3,875,002	579,920	29,030	.	4,483,952	86.4%	12.9%	0.6%	100.0%
2003	3,845,133	398,074	25,800	.	4,269,007	90.1%	9.3%	0.6%	100.0%
2004	2,513,702	231,062	27,984	.	2,772,748	90.7%	8.3%	1.0%	100.0%

Table 3.1.1 (3). Landings and numbers of trips by region and fishing year (August 6 - March 31).

Fishing	Northeast		Southeast		Florida Keys		West Coast		Unknown		Total	
Season	Trips	Pounds	Trips	Pounds	Trips	Pounds	Trips	Pounds	Trips	Pounds	Trips	Pounds
1985-86	250	25479	2616	402129	29139	4814587	302	98539	44	22336	32351	5363070
1986-87	215	21326	3521	548284	26927	4744159	401	47581	18	8816	31082	5370166
1987-88	322	26488	3687	486934	29967	4885206	431	29576	0	0	34407	5428204
1988-89	247	31122	3426	479546	32376	6620414	347	26967	35	4684	36431	7162733
1989-90	233	22382	4014	518576	35730	7271967	299	26415	0	0	40276	7839340
1990-91	378	36582	4396	534448	35529	5449441	233	25502	1	18	40537	6045991
1991-92	542	53565	5962	852962	38905	5872454	364	56998	0	0	45773	6835979
1992-93	577	58288	4372	578013	30515	4658609	354	73000	0	0	35818	5367910
1993-94	606	61846	4712	786398	25948	4428972	302	32574	0	0	31568	5309790
1994-95	532	47973	4405	618447	27415	6484897	202	30324	0	0	32554	7181641
1995-96	331	45209	4198	576843	28174	6375814	127	19268	0	0	32830	7017134
1996-97	390	50298	3986	628716	28370	7045683	103	19243	0	0	32849	7743940
1997-98	383	56963	3769	567197	29862	7010766	73	5233	0	0	34087	7640159
1998-99	513	59816	2853	453816	22777	4931882	55	2019	0	0	26198	5447533
1999-00	430	59166	3998	709463	23668	6884284	46	16293	0	0	28142	7669205
2000-01	585	93917	3127	433054	22461	4997096	75	44521	0	0	26248	5568587
2001-02	676	119614	2373	321729	16570	2609531	50	28508	0	0	19669	3079382
2002-03	555	78881	2472	323351	21102	4161657	57	13503	0	0	24186	4577392
2003-04	417	54776	2612	334126	19163	3763728	40	8536	0	0	22232	4161166

Table 3.1.1 (4). Identification of variables for the catch rate generalized linear models that explain at least 1% of the model's deviance. In all cases, the response variable was the pounds reported on trip tickets.

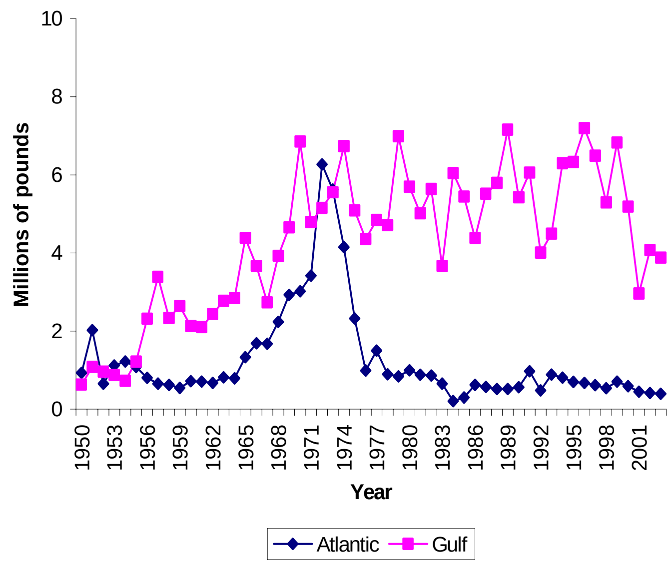
Gear	Source	df	Deviance	Dev/df	Δ dev/df	% Δ dev/df	Cum % Δ dev/df
Combined	Null	502215	642220	1.2788			
	FY	502197	626968	1.2485	0.0303	2.4%	
	Region	502214	640431	1.2752	0.0036	0.3%	
	Month	502208	573790	1.1425	0.1363	10.7%	10.7%
	With Month						
	FY	502190	560262	1.1156	0.0269	2.1%	12.8%
	Region	502207	571511	1.1380	0.0045	0.4%	
Traps	Null	182545	199201	1.0912			
	FY	182534	194140	1.0636	0.0276	2.5%	
	Region	182544	199174	1.0911	0.0001	0.0%	
	Month	182538	164575	0.9016	0.1896	17.4%	
	Trap Cat	182534	134069	0.7345	0.3567	32.7%	32.7%
	Soaktime	182544	194035	1.0629	0.0283	2.6%	
	With number of traps by category						
	FY	182523	129720	0.7107	0.0238	2.2%	
	Region	182533	133997	0.7341	0.0004	0.0%	
	Month	182527	118484	0.6491	0.0854	7.8%	40.5%
	Soaktime	182533	132014	0.7232	0.0113	1.0%	
	With number of traps by category and month						
	FY	182516	114342	0.6265	0.0226	2.1%	42.6%
	Region	180000	118339	0.6483	0.0008	0.1%	
	Soaktime	180000	118350	0.6484	0.0007	0.1%	
Divers	Null	33390	46983	1.4071			
	FY	33379	44466	1.3321	7.50%	5.3%	
	Region	33389	46240	1.3849	2.22%	1.6%	
	Month	33383	39715	1.1897	21.74%	15.5%	15.5%
	With Month						
	FY	33372	37845	1.1340	5.57%	4.0%	19.4%
	Region	33382	39676	1.1885	0.12%	0.1%	

Table 3.1.1 (5). Standardized commercial catch rates in pounds per trip for Southeast Florida and the Florida Keys and one-day trips by gear.

	Combined gears				Traps				Divers			
Fishing year	Number of Trips	Median	Lower 95%	Upper 95%	Number of Trips	Median	Lower 95%	Upper 95%	Number of Trips	Median	Lower 95%	Upper 95%
1985-86	22077	97.3	96.3	98.2								
1986-87	21088	106.5	105.4	107.5								
1987-88	24567	93.7	92.8	94.6								
1988-89	31386	119.7	118.7	120.6								
1989-90	34590	112.6	111.7	113.5								
1990-91	34985	86.0	85.2	86.7								
1991-92	38962	92.4	91.7	93.1								
1992-93	29294	93.6	92.8	94.4	13693	88.4	86.6	88.4	1361	45.9	44.0	46.6
1993-94	26882	103.1	102.2	104.0	13584	100.2	98.4	100.2	1515	45.5	43.9	46.2
1994-95	27044	117.6	116.7	118.6	14321	112.8	111.0	112.8	2633	49.9	48.5	50.4
1995-96	27505	114.8	113.9	115.9	16210	112.0	110.2	112.0	3026	52.0	50.7	52.5
1996-97	27875	122.5	121.6	123.5	16801	115.7	113.9	115.7	3085	56.8	55.3	57.3
1997-98	29036	116.7	115.8	117.7	19885	111.0	109.3	111.0	3400	58.2	56.8	58.7
1998-99	22195	105.5	104.5	106.5	15791	106.4	104.5	106.4	2743	61.3	59.8	61.8
1999-00	23775	124.6	123.6	125.7	15199	114.3	112.5	114.3	3370	73.8	72.1	74.5
2000-01	22867	104.6	103.6	105.5	15768	99.9	98.2	99.9	3320	71.5	69.8	72.1
2001-02	16925	88.4	87.4	89.3	11870	86.0	84.3	86.0	2765	65.2	63.7	65.9
2002-03	21350	108.8	107.8	109.8	15321	101.9	100.3	101.9	3033	71.5	69.8	72.2
2003-04	19813	109.6	108.6	110.7	14103	103.0	101.3	103.0	3140	64.4	62.8	64.9

Figure 3.1.1 (1). a) Landings by calendar year by coast and b) corrected landings from Florida's Atlantic coast.

a.



b.

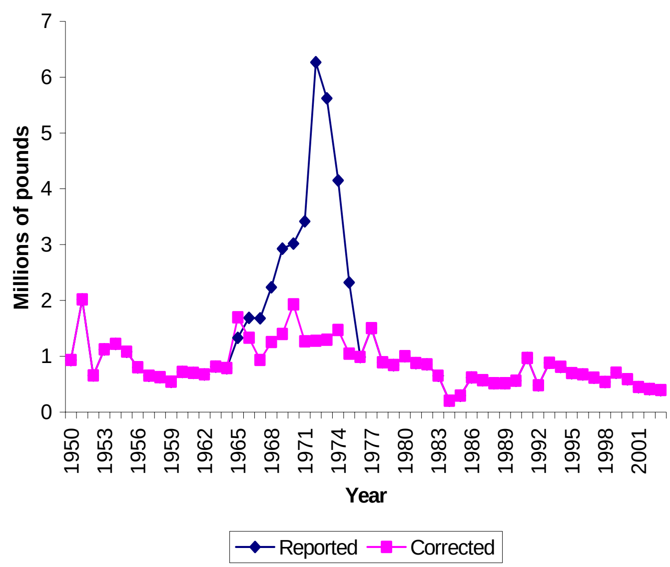


Figure 3.1.1 (2). Commercial landings of spiny lobster in the United States.

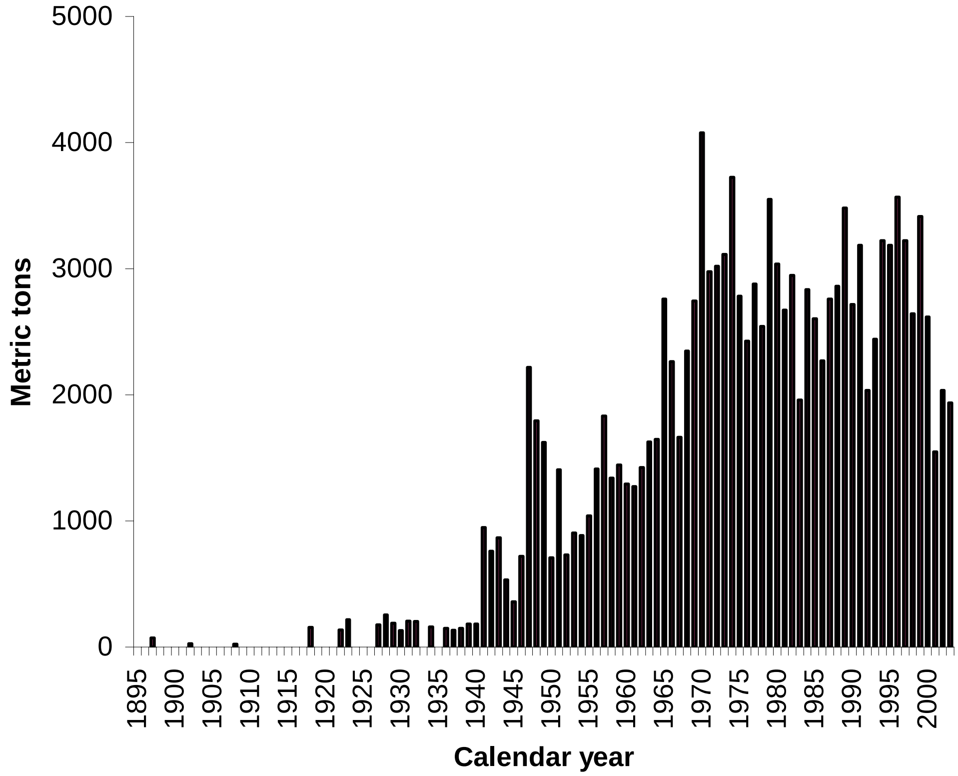


Figure 3.1.1 (3). Percentage of spiny lobster landings in 2003 by gear.

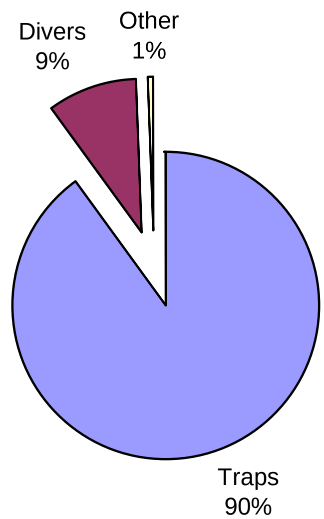
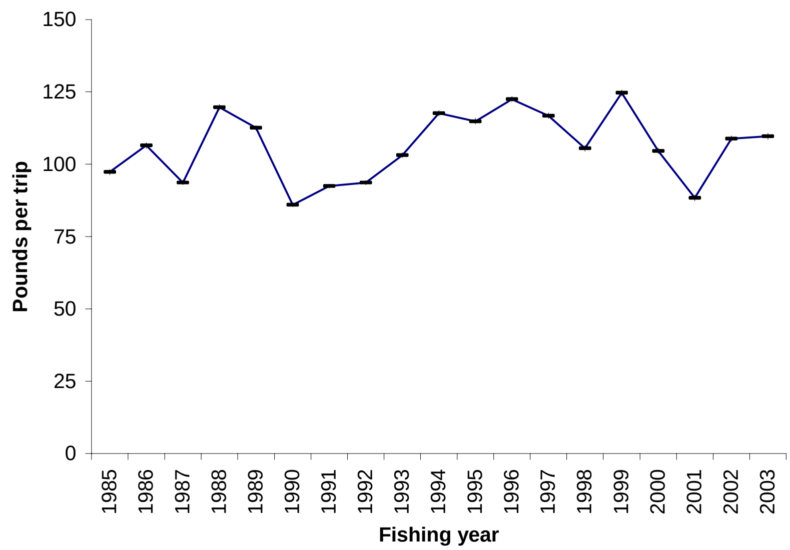


Figure 3.1.1 (4). Standardized commercial catch rates for Southeast Florida and the Florida Keys using only one-day trips by fishing year (a) and month (b). Both month and fishing year were significant in the generalized linear model. The vertical lines represents the 95% confidence intervals, and the horizontal lines are the seasonal means.

a.



b.

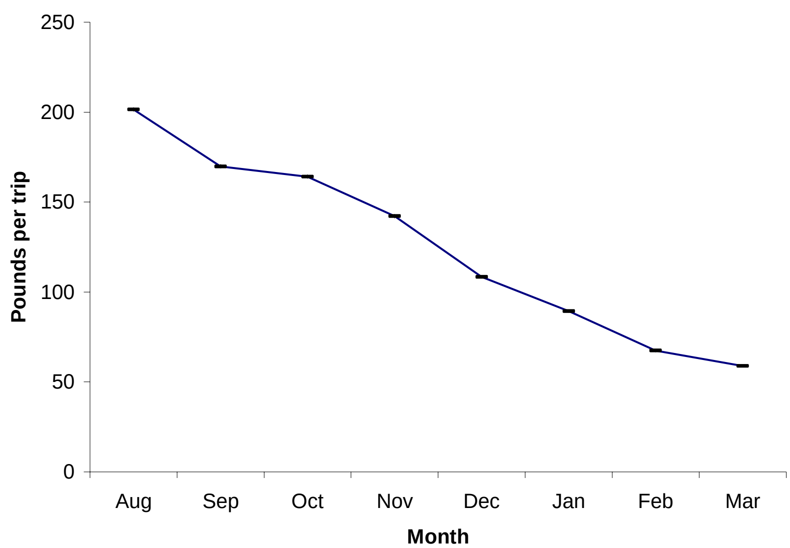


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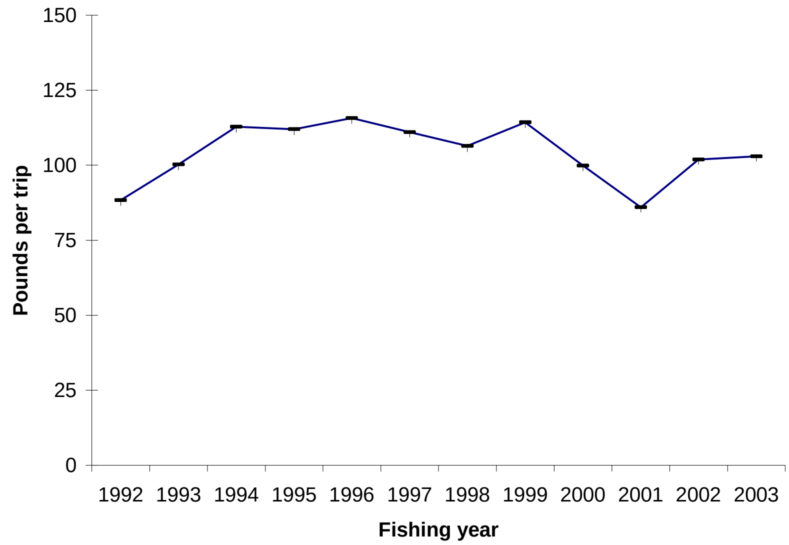
Figure 3.1.1 (5). Standardized commercial catch rates for traps by fishing year (a) and month (b) using trip tickets from Southeast Florida and the Florida Keys using only one-day trips. Both fishing year and month were significant in the generalized linear model. The vertical lines represents the 95% confidence intervals, and the horizontal lines are the seasonal means.

a.



b.

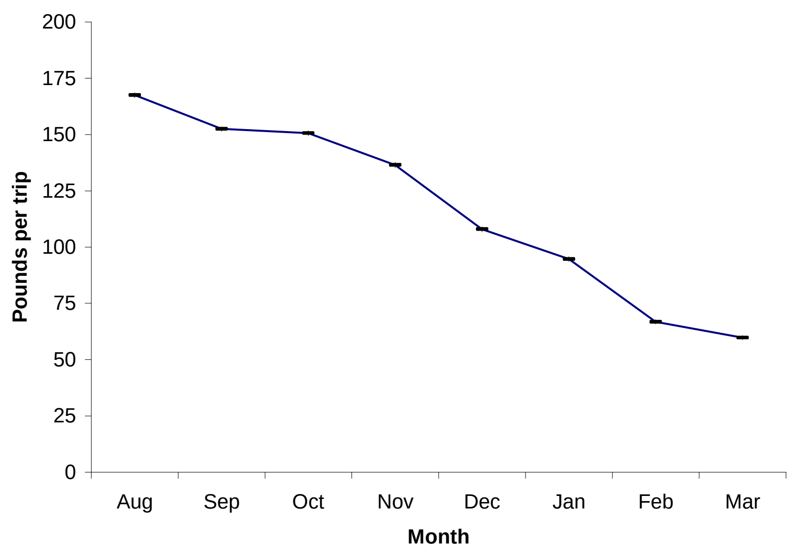
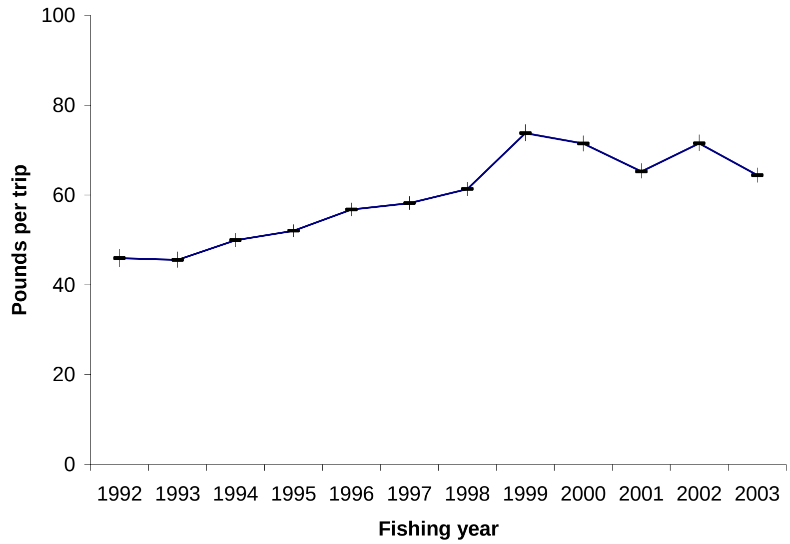


Figure 3.1.1 (6). Standardized commercial catch rates for divers by fishing year (a) and month (b) using trip tickets from Southeast Florida and the Florida Keys using only one-day trips. Both fishing year and month were significant in the generalized linear model. The vertical lines represents the 95% confidence intervals, and the horizontal lines are the seasonal means.

a.



b.

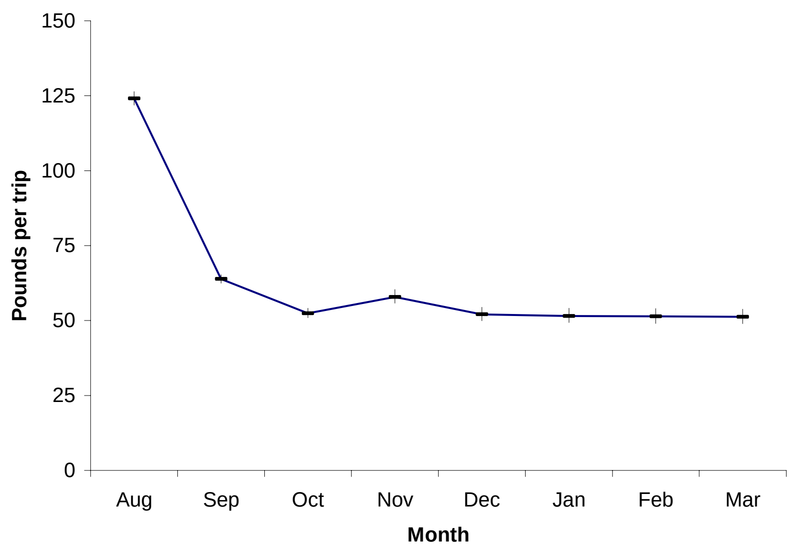


Figure 3.1.1 (7). Landings from the Western Atlantic region by the major producing countries.

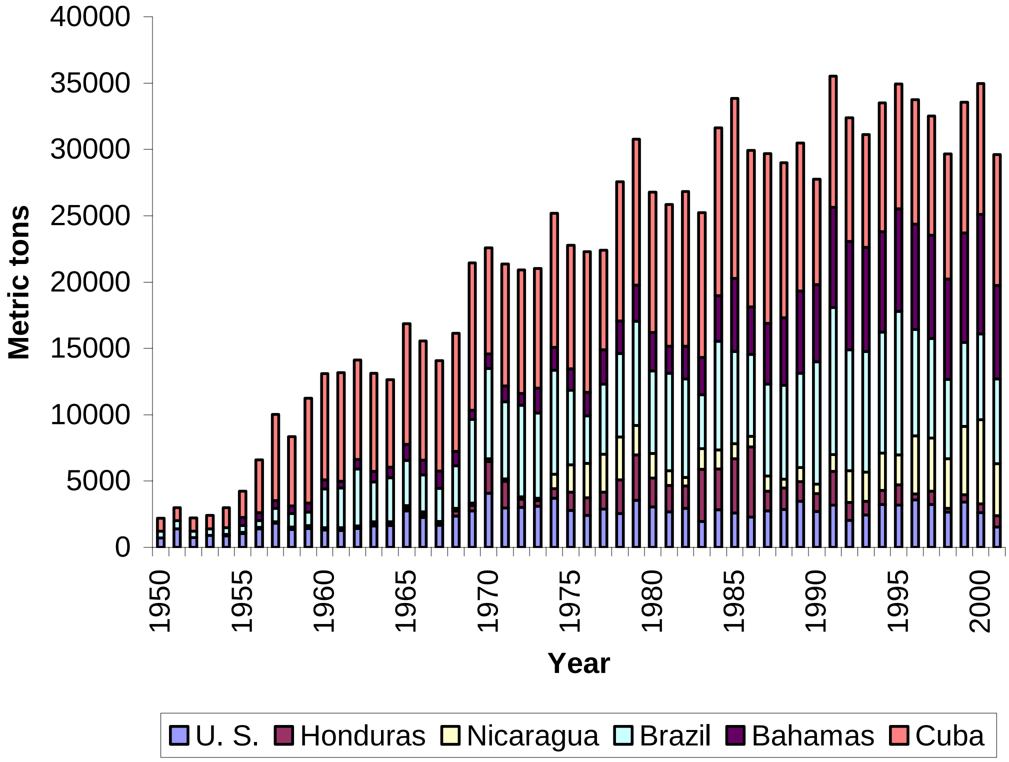
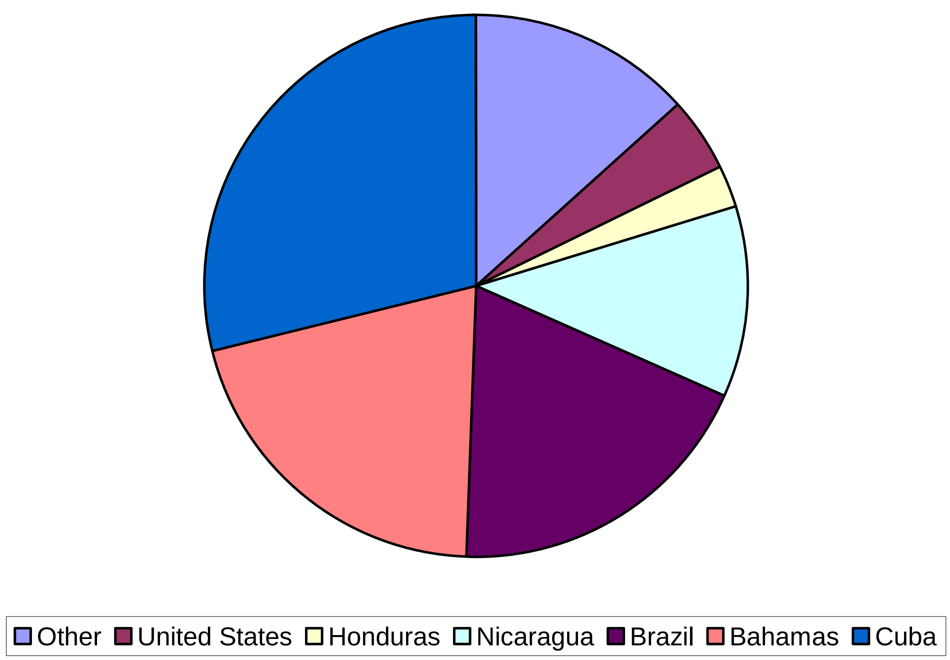


Figure 3.1.1 (8). Landings in 2001 (the most recent year) by the major producing countries in the Western Atlantic region.



3.1.2 Commercial Discards

Introduction

Florida's spiny lobster trap fishery is unusual in that part of the catch, usually sub-legal sized lobsters or occasionally legal-sized lobsters, is used to bait traps. Studies have shown that the catches in traps baited with shorts are approximately three times higher than with other baits such as cowhide, cat food, or dead fish (Heatwole et al. 1988). The question is how much additional mortality does the resource endure with this practice. The number of lobsters used for bait can broken into how many short lobsters are used to bait traps during the season and what is the survival rate of those animals.

Methods

FWC conducted an observer program from 1993-94 through the 2000-01 fishing seasons and information from that program can be used to address this issue. Among other questions, observers asked the fishers how they had baited the trap being examined. Observers recorded how many shorts, how many legal-sized lobsters, and the other bait such as cowhide, dead fish, canned fish, and cat food. Sub-legal lobsters from were defined as lobsters with carapace lengths between 60 and 75 mm and legal lobsters had carapace lengths of 76.2 mm (3 inches) and greater. Some records contained fractional numbers of lobsters because observers sample every other trap or every third trap and they pro-rated the bait. Fishers keep potential lobsters in their live wells until needed. From observer data, we estimated the mean number of shorts and legal-sized lobsters used for bait per trap by season, region, and month.

The next step was to estimate the number of trap hauls by season, region, and month. The average numbers of traps pulled per trip from trip tickets that specified traps were summarized by fishing season (*s*), region (*r*), and month (*m*). The number of lobsters used for bait was the product of the number of baits per trap and the number of trap hauls (Equation 1).

$$Hauls_{r.m.s} = (Traps / Trip)_{r,m,s} * Trips_{r,m,s} \qquad (1)$$

The number of lobsters ($Lob_{b,r,m,s}$) confined as bait was then

$$Lob_{b,r,m,s} = Hauls_{r,m,s} * Number_b / Haul_{r,m,s} \qquad (2)$$

where *b* designates short or legal sized lobsters used for bait (Equation 2).

Hunt et al. (1986) estimated the average mortality of lobsters used as bait at 26.3% for four weeks and which is equivalent to an instantaneous rate of 0.0109 per day. However in discussions at the Data Workshop, it was pointed out that Hunt et al's work addressed the exposure of bait lobsters and that since 1987 boats had to be equipped with live wells in order to keep shorts on board. Therefore we need to use a lower mortality rate after the implementation of live wells. Hunt (personal communication) recommended using the mortality rates for there controls (10.1% for four weeks or an instantaneous rate of 0.00380 per day). The number of lobsters (both shorts and legal sized) that were estimated to have died during a month was the total number of bait lobsters per stratum, the average soak time in days, and the daily mortality rate prior to 1987 (Equation 3a) or afterwards (Equation 3b).

$$Deaths_{b,r,m,s} = Lob_{b,r,m,s} * (1 - e^{-0.0109 * Soaktime}) \qquad (3a)$$

$$Deaths_{b,r,m,s} = Lob_{b,r,m,s} * (1 - e^{-0.00380*Soaktime}) \qquad (3b)$$

Results and Disccussion

The estimated number of trap hauls per fishing year and the lobsters confined as bait are shown in Table 1. On average, fishers pull almost seven million traps over a typical season and they used 11.0 million sub-legal lobsters and 0.5 million legal sized lobsters as bait. Note that this model captured the effect of Hurricane Georges in 1998 when many fishers lost their traps. There is a strong seasonal pattern to bait usage because until the season has progressed a bit, there are not many sub-legal lobsters available and fishers bait with other baits, legal lobsters and whatever they can (Fig 1). Within a few weeks, more sub-legal lobsters are available and the use of legal lobsters declines and the traps are baited with more sub-legals (Fig. 2).

Not only is there a seasonal pattern in the number of lobsters that fishers use for bait, but the number of trap hauls also varies during the season with many traps being pulled when the season opens in August and then a tapering off of effort as some fishers move to other fisheries such as stone crabs (Figure 3).

The mortality of bait lobsters depends upon the soak time and soak times are shorter in the early season and then get longer (Figure 4). Since the observer program operated after live wells were required, we used the 10.1% over four weeks to estimate the number of lobsters that died as a result of being used for bait. On average, less than 0.5 million lobsters died during the fishing eight month fishing season (Table 1) which is less than half of what Hunt et al. (1986) predicted for using only one bait per trap.

Using this model, the average number of sub-legals and legal-sized lobsters per month in Figure 4 and the trip ticket data such as estimated traps per pound, the pounds landed by traps, and the soak times allow us to extend the bait estimates back to earlier years (Fig. 5).

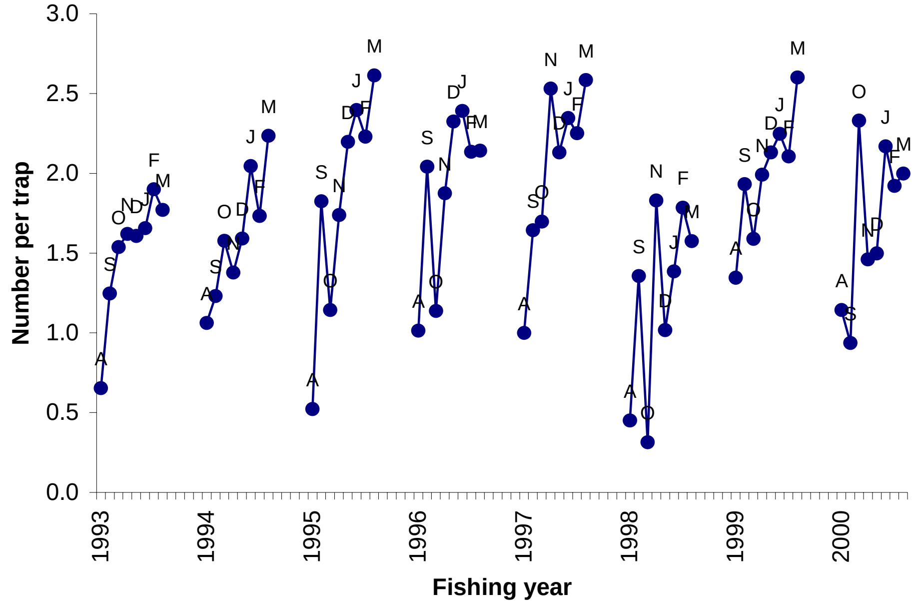
This model probably over-estimates the number of lobsters confined as attractants because it uses estimated trap hauls and the average number of baits per trap to arrive at the number of bait lobsters when, especially early in the season when soak times are short, sub-legal lobsters are re-used from one set of the trap to the next.

Table 3.1.2 (1). Estimated numbers of lobsters used as bait and the number that died as a result of being confined based on the FWC observer program. The bait mortality was 10.1% over four weeks based the controls in Hunt et al. 1986.

Fishing	Bait usage					Bait Mortality			
Year	Landings (lb)	Trap Hauls	Shorts	Legals	Total bait	Ave bait / trap	Shorts	Legals	Total bait
1993	5,109,464	7,178,306	9,722,203	251,608	9,973,811	1.39	413,930	8,686	422,617
1994	6,893,968	7,755,461	11,530,549	676,680	12,207,230	1.57	470,527	21,911	492,439
1995	6,676,451	7,668,209	11,939,043	554,977	12,494,020	1.63	495,107	17,928	513,035
1996	7,335,547	7,733,807	13,090,248	1,009,931	14,100,179	1.82	549,376	34,316	583,692
1997	7,097,950	7,868,428	14,370,630	427,713	14,798,343	1.88	606,392	14,749	621,140
1998	4,864,200	5,433,270	5,757,398	352,503	6,109,901	1.12	264,970	11,006	275,976
1999	6,882,285	6,563,086	12,115,455	510,228	12,625,683	1.92	482,315	15,833	498,148
2000	4,717,168	6,432,743	9,810,643	390,772	10,201,415	1.59	410,927	12,112	423,038
Average	6,197,129	7,079,164	11,042,021	521,802	11,563,823	1.62	461,693	17,068	478,761

Figure 3.1.2 (1). Number of sub-legal (a) and legal-sized (b) lobsters used as bait by month.

a.



b.

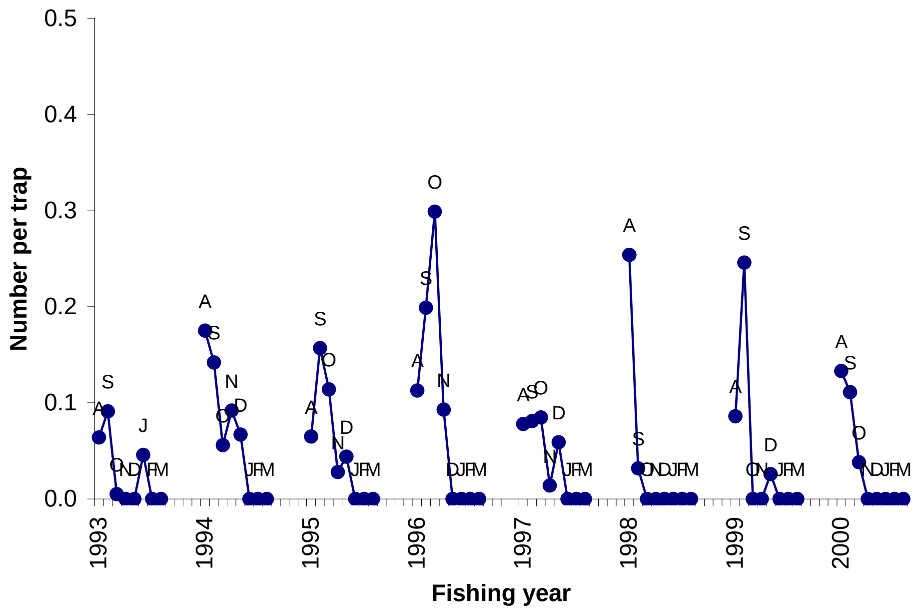


Figure 3.1.2 (2). Average numbers of sub-legal (shorts) and legal-sized (legals) confined per trap by month across fishing years. The error bar is one standard deviation.

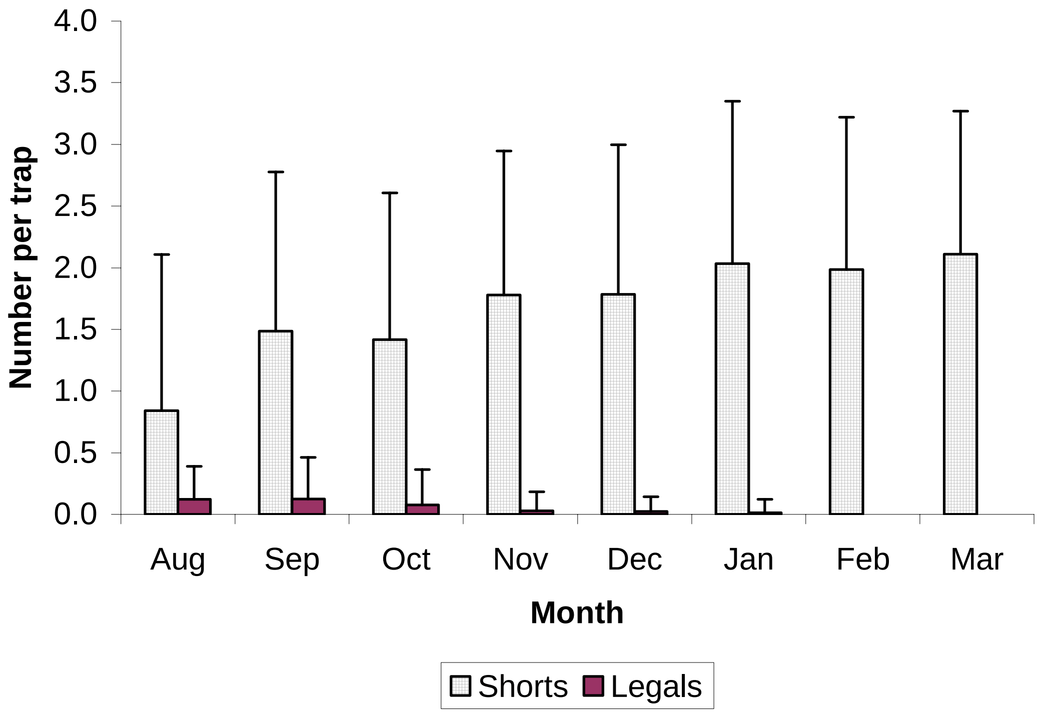


Figure 3.1.2 (3). The estimated number of trap hauls per month illustrating the strong seasonal pattern.

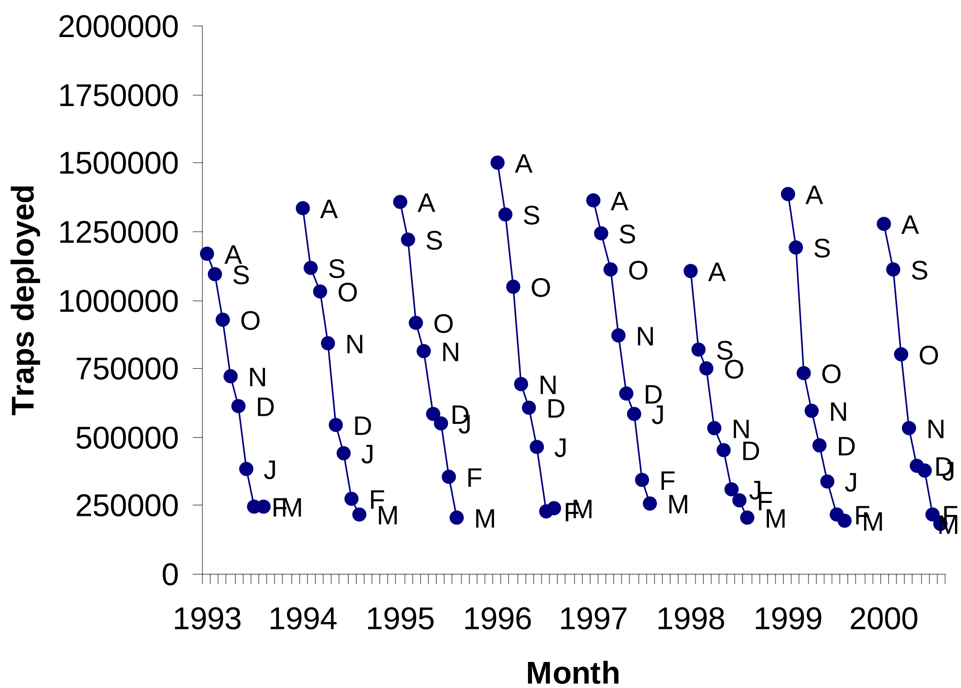


Figure 3.1.2 (4). Average soak time in days by month based on the FWC observer data (1993-2000 fishing years). The vertical lines are the 95%-confidence intervals, the horizontal lines are the means.

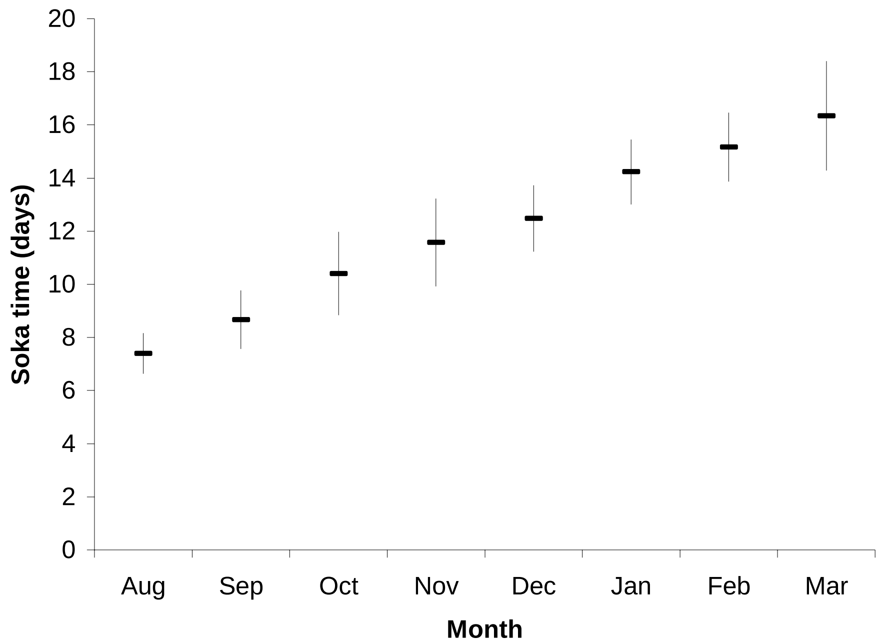
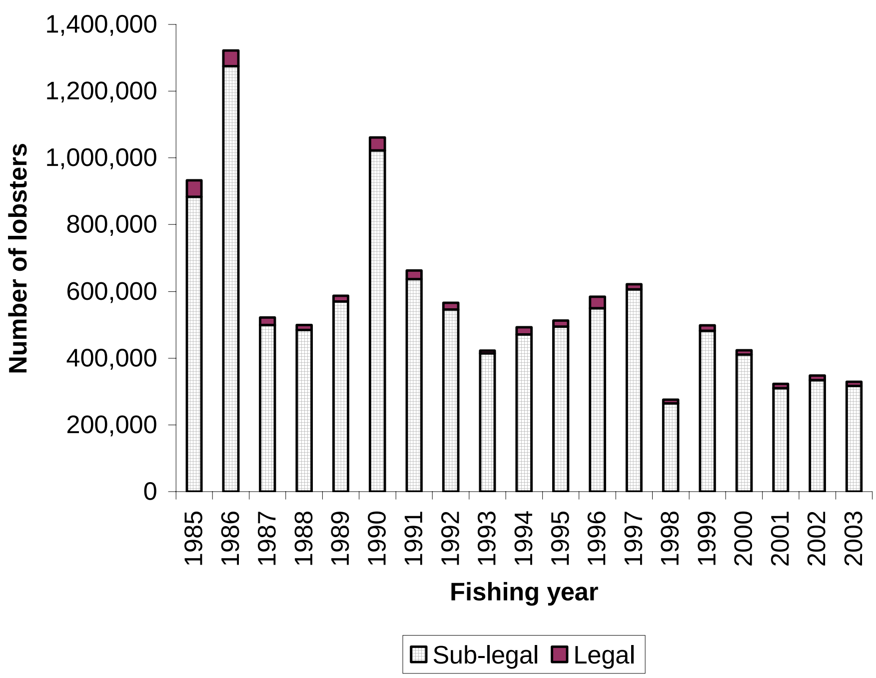


Figure 3.1.2 (5). Estimated numbers of lobsters used for bait by fishing year.



3.1.3 Fishing Effort

The measurement of fishing effort is an important component in the evaluation of catch statistics. Fishing effort in a trap fishery can be measured several ways, each of which may have specific strengths and weaknesses. Herein, we will present several measures of fishing effort and discuss the relative strengths and weaknesses of each method as they relate to the determination of catch per unit effort.

The principal management tool of the lobster fishery in Florida is based on the control of the number of traps. The number of traps in the fishery prior to 1993 was determined from the NMFS canvas of commercial fishermen. And subsequently by the number of trap certificates issued and delivered to fishermen. The number of traps in the fishery doubled and was subsequently reduced by half over the last 30 years with little apparent affect on landings (Figure 1). Effort management by controlling the number of traps is very attractive to fishery managers because it is relatively easy to allocate permits or otherwise control the number of traps that are available to the fishery. The number of traps in the fishery is a measure of fishing effort that is easily assessed by fishermen based on their own experience and observations of the number of traps they use. The determination of fishing effort in trap fisheries is more complicated. A trap can be deployed (soaked) for indeterminate lengths of time. As the trap soak period changes so does the fishing efficiency of the trap (Figure 2). Traps can also be lost, damaged, removed from service during the fishing season, or not utilized at all. The variable use of traps for different portions of the fishing season results in a variable number of trap deployment days each fishing season without necessarily changing the number of traps available to the fishery (Figure 3). The change in the duration of trap use during the fishing season was most apparent during the high landings seasons of 1996-97 and 1997-98 when trap deployment days increased 24% while the number of traps available to the fishery decrease 19% (Figure 2). The number of trap deployment days is an more appropriate measure of fishing effort than the number of traps, but it is still affected by changes in the catchability coefficient during the fishing season and with different soak periods.

The number of fishing trips is another measure of fishing effort that is readily available. The number of lobster fishing trips has been recorded by the trip ticket program since 1987 and is shown here beginning in 1993 (Figure 4). The number of trips reported each fishing season is correlated with annual landings and therefore appears to be the most appropriate measure of fishing effort in this fishery. The number of trips meets some of the criteria of an appropriate measure of fishing effort because the number of traps soak period and length of the fishing trip (one day) have not changed since 1993 giving some consistency to the trip as a stable unit of effort (Figure 4). However, the number of traps per trip has increased 20%, making the number of trips a less an inconsistent measure of fishing effort. An additional incongruity with fishing trips as a measure of effort is the intractable component of fishermen experience and ability. The number of fishermen using traps declined 44% between 1993 and 2003; and presumably, those fishermen that left were less capable or less efficient than those that remained.

The appropriateness of any measurement fishing effort is often assessed based on its correlation with landings. For the lobster fishery, there does not appear to be a measure of fishing effort that reflects landings with the exception of the number of fishing trips, which as discussed previously, may be dependent upon landings, not a factor controlling landings. One explanation for the lack of a relationship between fishing effort and landings is that fishing effort is saturated and the recent changes in fishing effort have not changed this condition.

The hypothesis that the fishery is effort saturated is not consistent with many fishermen's individual experience. The disconnect between an individual fishermen's experiences and the overall level of fishing effort may be rooted in the amount of variation in fishing effort between different fishermen. That is, some fishermen catch more than others. One way to visualize the variability in catch per trap is to rank fishermen by their average catch per trap from lowest to highest and plot the cumulative landings by the cumulative number of traps they used (Figure 5). In 1993-94 the cumulative-catch curve was relatively flat indicating that many traps had relatively low catch rates. By 2003-04 the cumulative-catch curve was relatively steeper, indicating that there were less traps with low catch rates in the fishery in 2003-04 than in 1993-94 (Figure 5). This shift occurred despite there being less lobster landed in 2004-05. The flat portion of the 2003-04 cumulative-catch curve also indicates that approximately 100,000 traps were apparently not used as they are not associated with any reported landings (Figure 5).

Figure 3.1.3 (1). Landings and the number of traps used each fishing season in Florida's commercial spiny lobster fishery.

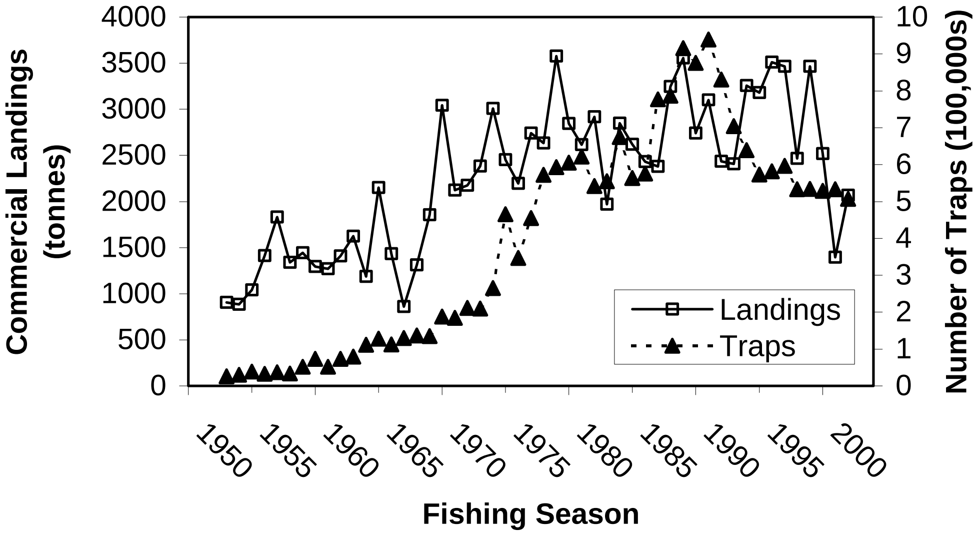


Figure 3.1.3 (2). The mean number of traps used each fishing trip and the average number of days each trap was deployed (trap soak period).

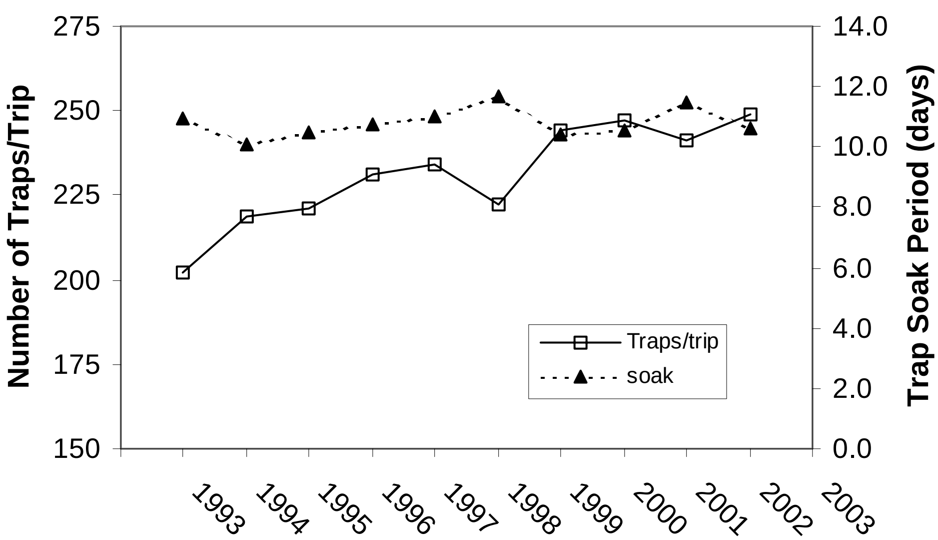


Figure 3.1.3 (3). Total allowable fishing effort, measured by the potential-cumulative number of days traps could be deployed, and actual fishing effort, measured by the cumulative number of days traps were deployed.

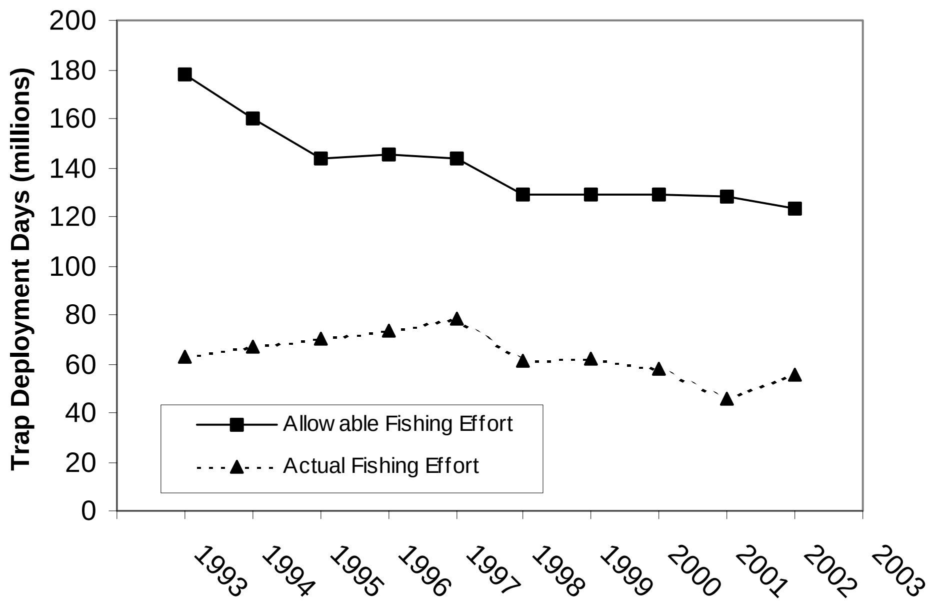


Figure 3.1.3 (4). The number of fishermen landing lobsters using traps and the number of fishing trips that used lobster traps each fishing season.

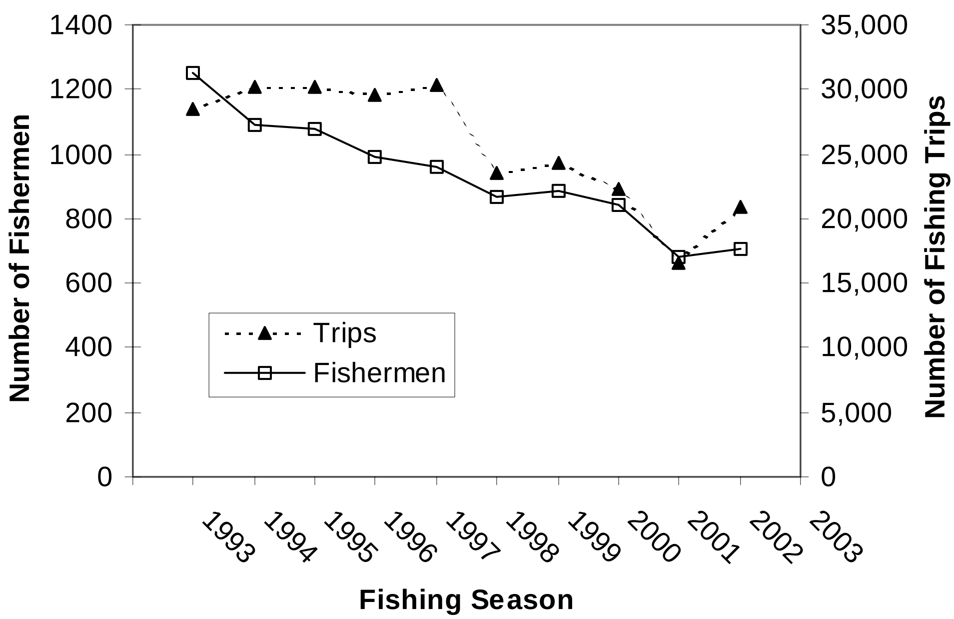
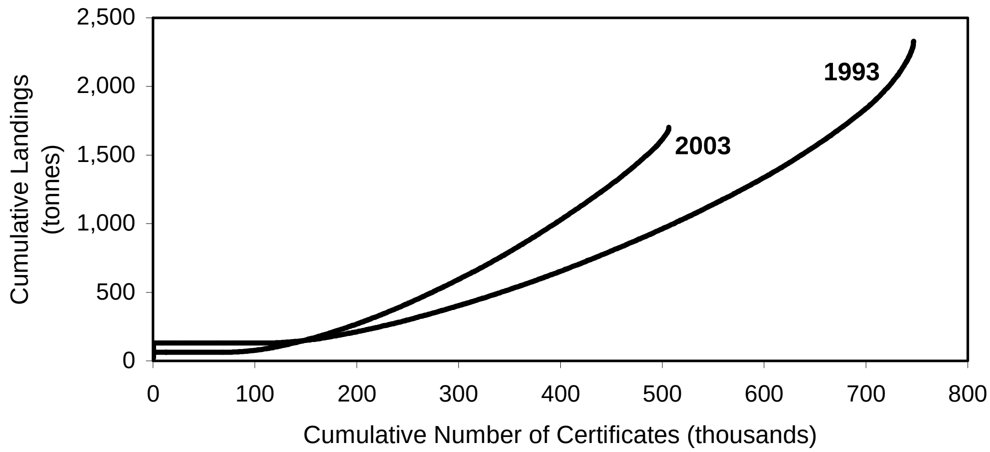


Figure 3.1.3 (5). The relationship between the number of certificates an individual owned and their landings plotted from the lowest catch per trap to the highest for the first (1993) and most recent (2003) fishing season since the implementation of the lobster trap certificate program.



3.2 Recreational Fishery

3.2.1 Overview

The FWC has collected information on the Florida recreational spiny lobster fishery from three sources. First, and most importantly, since 1992 annual mail surveys of persons that possess a valid Florida recreational crawfish license have been conducted to provide regionally-explicit estimates of recreational lobster fishing effort, landings and fisher demographics and have also been used to acquire socio-economic information about the fishery and fisher's opinions about existing or potential changes in regulations governing the fishery. Lobster landings and effort survey encompasses the peak period of the Florida lobster fishing: The Special Two-Day Sport Season held on the last Wednesday and Thursday in July and the period from the opening day of the regular season (August 6) through Labor Day. A detailed description of the results of these surveys can be found in Sharp *et al.,* in press.

Additional information about the recreational lobster fishery is available from persons holding the Florida Special Recreational Lobster License (SRL). This license is available to a select few persons and has a higher bag limit than the regular Florida recreational crawfish license. SRL holders are required to report all their lobster fishing activities under this license to the FWC. Although the number of persons that possess this license and their proportion of recreational lobster landings compared to that modeled by the mail surveys of regular crawfish license holders is negligible (> 1%), the mandatory reporting requirement associated with this license allows the FWC to monitor recreational lobster fishing effort for the entire season (August 6 through March 31).

Finally, during 2002 the FWC conducted a creel survey of recreational lobster fishers in the Florida Keys and collected catch and effort and lobster length-frequency data during the Special Two-Day Sport Season and during the first two weeks of the regular season. The primary purpose of this single-season project was to evaluate the presence of recall and prestige bias in the annual mail surveys of recreational lobster license holders described above. This project is described in detail in Fishery-Dependent Survey Data section of this report.

3.2.2 Recreational Landings

Recreational landings are estimated using mail surveys. Rcipients of FWC mail surveys are randomly selected from the state's saltwater fishing license database of individuals who purchased a lobster permit that was valid during the survey period. To ensure that this selection process does not over- or under- sample any geographic region, these selections were stratified based upon license sales in each of 10 residence areas defined by postal codes (Fig. 1). The number of lobster license holders that have been attempted to survey each season has ranged from 4,000 to 5,000, with an exception in 2001. That year's survey included a detailed socio-economic component, which necessitated a much more detailed questionnaire than those mailed during other years. In anticipation of a decreased response rate resulting from the additional length, the FWC attempted to survey 10,000 license holders. The general methodology of the mail survey follows the "Total Design Method" (Dillman 1978). Surveys are mailed to the license holders chosen to receive a questionnaire about the Special Two-Day Sport Season a week after the end of that season, and those chosen to receive a regular-season questionnaire are mailed their surveys one week after Labor Day. A personally addressed, signed cover letter and a postage paid return envelope accompany each questionnaire. Anonymity is guaranteed to each survey respondent. One week after the initial mailings, each addressee is mailed a "thank you/reminder" postcard. Survey recipients who had not returned their questionnaires after about 7 weeks after it was mailed to them are sent a reminder letter and a replacement questionnaire. To provide an incentive for recipients to return their completed questionnaires, each recipient is offered the option of receiving a brief summary of the results of the survey.

Landings and fishing effort are derived from the questionnaires for a particular survey by estimating the number of fishers participating in a particular season, the time (in days) they fished for lobster, and their lobster catch rate (lobsters per day). We used a sampled randomization technique (Monte Carlo) to calculate these basic parameters (Sokal & Rohlf 1981). This method entails generating 1,000 independent bootstrap samples. Samples were weighted by the 10 geographic residence areas (Fig. 1) based on the proportion of the total number of surveys mailed to each area. A pilot study found that lobster catch rates of recreational fishers can vary considerably between those areas, as do the recreational fishers' response rates (Bertelsen & Hunt 1991). Thus, this weighting factor is used to ensure that one area is not over-sampled relative to the others. Equations 1–6 below describe the detailed calculations used to estimate landings and fishing effort (person-days) during the Special Two-Day Sport Season for each of the 1,000 bootstrapped samples. For each residence area, the number of licensed lobster fishers that fished for lobster during the survey period is calculated. The percentage of those that fished for lobster during the survey period was then multiplied by the number of lobster licenses sold that year to persons that lived in each of our defined residence areas to determine the total number of licensed fishers residing in each of those areas that fished for lobster:

1)

$$LF_r = \left(\sum L_r \times P_r \right)$$

where LF = number of licensed fishers; L = number of lobster licenses estimated to be valid during the survey period; *P* = proportion of survey respondents that fished for lobster during the survey period; and r = residence region.

Using equation 2, the number of license holders fishing for lobsters in each of seven fishing zones (Fig. 2) is determined by estimating the number of licensed fishers in each zone on the first and second day of the season. This equation yields the number of fishers in each zone from each residence area on each day. The total number of fishers in each zone is then determined by summing the number of persons from all the residence areas that fished in a particular zone:

2)

$$LF_{zd} = \left(LF_r \times \frac{\sum n_{rzd}}{\sum n_r} \right)$$

where LF = number of licensed lobster fishers; n = survey respondents that fished for lobster; r = residence area; z = fishing zone; d = day of the season.

Using equation 3, the number of fishing parties (NG) in each fishing zone on each day is estimated. This is done by dividing the number of licensed fishers (LF) in that zone by the mean licensed group size. If non-licensed lobster fishers (i.e., those younger than 16 and Florida residents older than 65) were included, this calculation would underestimate the total number of fishing groups in each fishing zone. Therefore, the non-licensed fishers (NL) are subtracted from the total fishing party size (GZ). The number of groups fishing in each fishing zone is equal to the number of licensed fishers that fished in a given zone (LFj), divided by the average licensed group size:

3) $$NG_{zd} = \frac{LF_{zd}}{\left(\frac{\sum GZ_{zd}}{n_{zd}} - \frac{\sum NL_{zd}}{n_{zd}}\right)}$$

where NG = number of lobster fishing parties; GZ = number of persons in the fishing party (includes both licensed and non-licensed persons); NL = number of non-licensed fishers in the party; and n = number of observations.

Using equation 4, lobster landings are calculated separately for the first and second day of the season in each zone. This is equal to the mean number of lobsters caught per fishing party (GC), multiplied by the number of fishing parties (NG) found in Equation 3, multiplied by the mean number of fishers per fishing party (GZ). Landings for each day in each fishing zone are then summed to estimate total landings:

4) $$L_{zd} = GC_{zd} \times GZ_{zd} \times NG_{zd}$$

where L = lobster landings (number of lobsters).

Using equation 5, the number of person-days in each fishing zone on each day are calculated.

5) $$PD_z = \sum D_{zd} \times GZ_{zd}$$

where PD = number of person-days; D = number of days spent lobster fishing.

Estimating fishing effort and landings for the regular season involves most of the same steps described above. However, because the survey period extends about 1 month, survey recipients are asked about their average daily lobster landings and fishing party size. Therefore, Equations 1 through 3 are based upon the respondents' average daily fishing activities. To estimate landings during the regular season, the average number of days the respondents fished in each fishing zone is calculated. Then, for each fishing zone, that value is multiplied by the average fishing-party catch rate (GC), fishing-party size (GZ), and the number of fishing parties (NG):

6) $$L_z = GC_z \times GZ_z \times NG_z \times D_z$$

Finally, landings values, which are in numbers of lobsters, are converted into an estimate of weight using the equation of Matthews et al. (2003):

7) $$LWT_j = 0.001989 \times CL^{2.80327}$$

where LWT = lobster landings (g); and CL = mean carapace length of lobsters sampled by the FWC's trip interview program of commercially landed lobsters in the Florida Keys during the first month of the lobster fishing season.

The effective survey response rates (*i.e.,* the percentage of completed survey questionnaires returned to the FWC after surveys that did not reach their license holders because of an incorrect address had been excluded) remained *c.* 60% each fishing season from 1993 through 1997 (Table 1). In 1998, the survey was lengthened as questions were added to the survey to obtain fishers' opinions about the fishery and to examine fisher demographics in more detail than earlier surveys. Since the surveys were lengthened, the combined return rates ranged from 45% to 52%, the exception being in 2001, when the survey also included a socio-economic component that resulted in a multi-page questionnaire. The combined return rate from both surveys that season was 43%.

Fishing effort during the Special Two-Day Sport Season from the 1992 through the 2003 fishing seasons, expressed in terms of person-days has ranged from c. 60,000 to 112,000 person-days (Fig. 3). Fishing effort was concentrated in the Florida Keys, where effort has ranged from 39,000 to 79,000 and accounted for 64% or more of the statewide fishing effort estimate each season. Most of the remaining fishing effort occurred along the SE coast of the state (*i.e.,* zones 4 and 5; Fig. 2), where effort ranged from 16,000 to 36,000 person-days. Fishing effort throughout the remaining areas of the state (*i.e.,* zones 1,2,6 & 7) ranged from *c.* 2000 to 10,000 person-days. Annual landings during the Special Season have ranged from *c.* 249,000 to 568,000 lbs (Fig. 4). The largest proportion of landings occurred in the Florida Keys and have ranged from 163,000 to 397,000 lbs, or *c.*60% to 70% of the annual statewide total. Landings along the SE coast during the Special Season ranged from 70,000 to 151,000 lbs, and those throughout the remainder of the state ranged from 5,000 to 58,000 lbs.

Statewide fishing effort during the regular season survey period from 1992 through 2003 ranged from *c.* 260,000 to 514,000 person-days (Fig. 5). Regional fishing effort was proportionally similar to that of the Special Two-Day Sport Season. Fishing effort in the Florida Keys over the same period ranged from 157,000 to 366,000 person-days. Most of the remaining fishing effort occurred along the Southeast coast of Florida, where effort ranged from 62,000 to 150,000 person-days. Effort in the rest of the state ranged from 25,000 to 66,000 person-days. Statewide landings during the regular season survey period ranged from 809,000 to 1,883,300 lbs (Fig. 6). The largest proportion of landings occurred in the Florida Keys and ranged from 497,000 to 1,274,000 lbs. As with the Special Season, landings in that region accounted for *c.* 60 to 70% of the annual statewide total. Landings in the south-east coast ranged from 229,000 to 624,000 lbs, and landings in the remainder of the state ranged from 42,000 to 169,000 lbs.

To obtain a coarse estimate of lobster fishing effort after the Labor Day holiday, mail surveys from 1993 through 1996 included questions that asked respondents about which month they intended to fish for lobsters after the survey period. Nearly 60% of respondents to the regular season survey had fished for lobsters before Labor Day, but only 37% of respondents to both surveys indicated they intended to do so during the remainder of September, and that percentage progressively decreased during the subsequent months (Fig. 7). However, an end-of-season mail survey that was conducted after the conclusion of the 1994 lobster fishing season indicated that lobster fishing effort during those months was even lower than that indicated by respondents of the former surveys. Only 13% of those survey recipients indicated that they actually fished for lobsters after Labor Day, and no more than 10% of those respondents fished for lobster in any single month during the survey period. From that same survey, we estimated that statewide there were only *c.* 50,673 (±1SD = 9,163) person-days of lobster fishing during that period and that *c.* 148,000 (± SD = 39,000) lbs of lobsters were landed. Because of the small number of surveys from which these estimates were derived (*n* = 52), regional landings were not estimated. Comparing this estimate to estimates from the Special Two-Day Season and regular season during 1994 indicated that less than 7 % of lobster landings that season occurred after Labor Day.

Table 3.2.2 (1). Number of questionnaires mailed to recreational lobster license holders, the number of completed questionnaires returned to the Florida Fish & Wildlife Conservation Commission, and the effective return rate of surveys from the 1993 through the 2002 seasons. Effective return rate is the percentage of returned questionnaires out of the total, once undeliverable questionnaires were removed.

	No. of Questionnaires			
Season	Mailed	Returned	Undeliverable questionnaires	Effective response rate (%)
Special Two-Day Sport Season				
1993	2491	1302	410	63
1994	2283	1184	402	63
1995	1996	983	327	59
1996	1998	962	377	59
1997	1981	984	311	59
1998	2076	1074	127	55
1999	1884	844	174	49
2000	2002	948	177	52
2001	4809	1974	466	45
2002	2500	1082	249	48
Regular Season				
1993	2497	1189	459	58
1994	2295	1137	400	63
1995	1686	860	236	59
1996	1999	930	357	57
1997	2006	954	325	57
1998	1967	910	110	49
1999	2031	839	189	46
2000	2002	820	225	46
2001	5181	1883	523	40
2002	2500	972	287	44

Figure 3.2.2 (1). Map of Florida showing residence area defined by zip codes used to stratify FWC mail surveys.

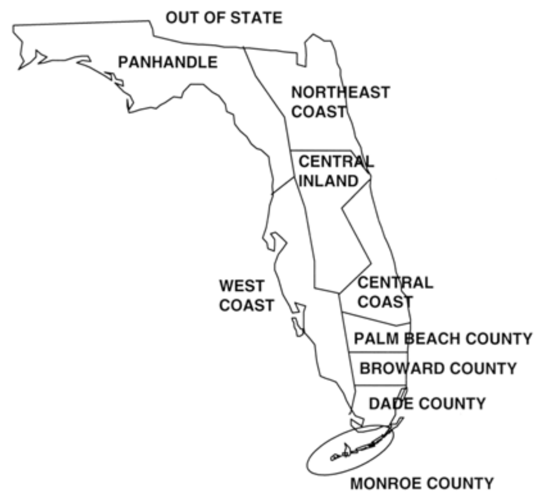


Figure 3.2.2 (2). Map of Florida showing fishing zones used to report regional recreational lobster landings and fishing effort.

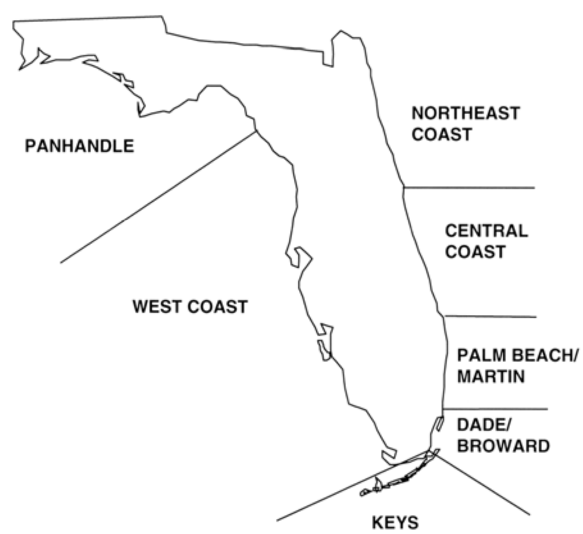


Figure 3.2.2 (3). Estimated fishing effort during the Special Two-Day Sport Season: A, statewide; B, in the Florida Keys; C, southeast coast; and D, in the remaining areas of the state based upon mail survey returns, 1992-2003. Fishing effort from the 1992 season was not estimated using a sampled randomization procedure.

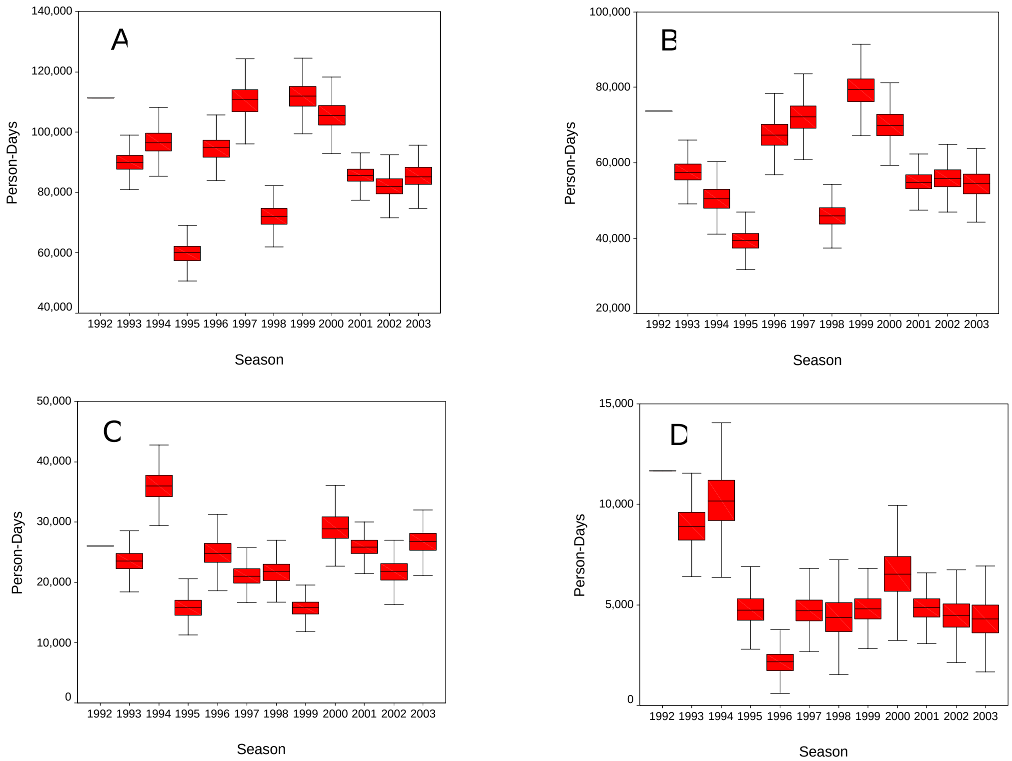


Figure 3.2.2 (4). Estimated lobster landings during the Special Two-Day Sport Season: A, statewide; B, in the Florida Keys; C, southeast coast; and D, in the remaining areas of the state based upon mail survey returns, 1992-2003. Landings from the 1992 season were not estimated using a sampled randomization procedure.

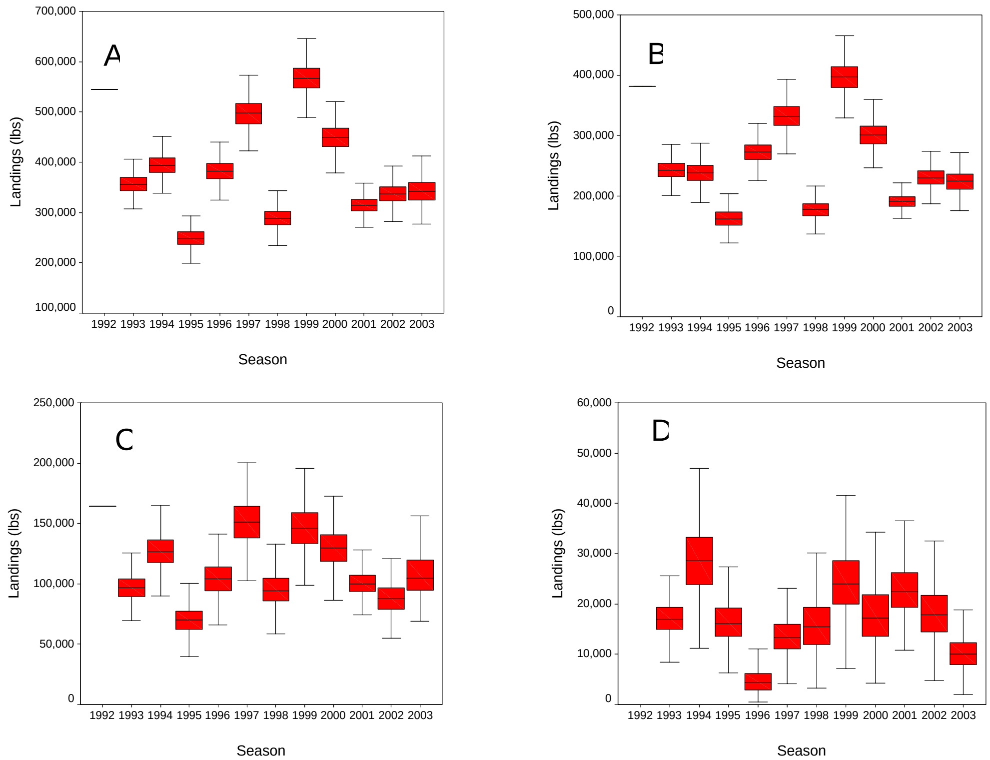


Figure 3.2.2 (5). Estimated fishing effort from opening day through Labor Day of the regular lobster fishing season: A, statewide; B, in the Florida Keys; C, southeast coast; and D, in the remaining areas of the state based upon mail survey returns, 1992-2003. Fishing effort from the 1992 season was not estimated using a sampled randomization procedure.

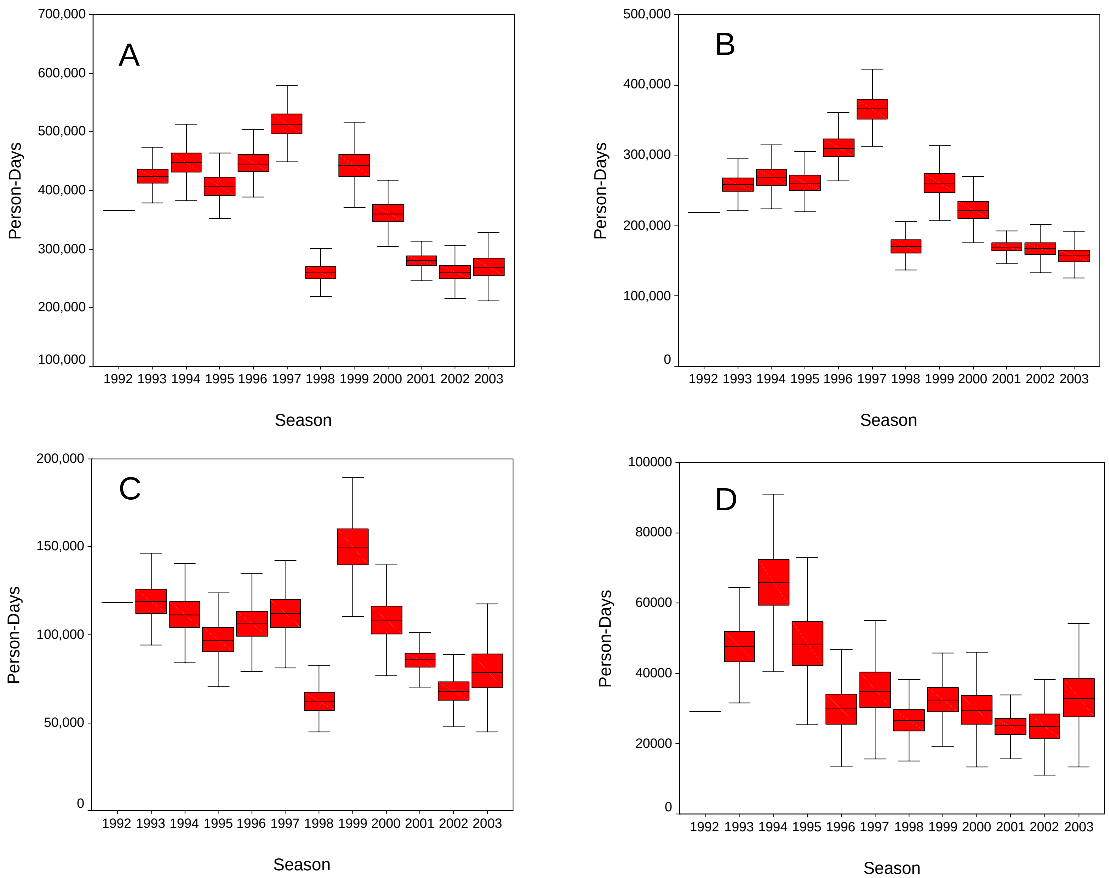


Figure 3.2.2 (6). Estimated lobster landings from opening day through Labor Day of the regular lobster fishing season: A, statewide; B, in the Florida Keys; C, southeast coast; and D, in the remaining areas of the state based upon mail survey returns, 1992-2003. Landings from the 1992 season were not estimated using a sampled randomization procedure.

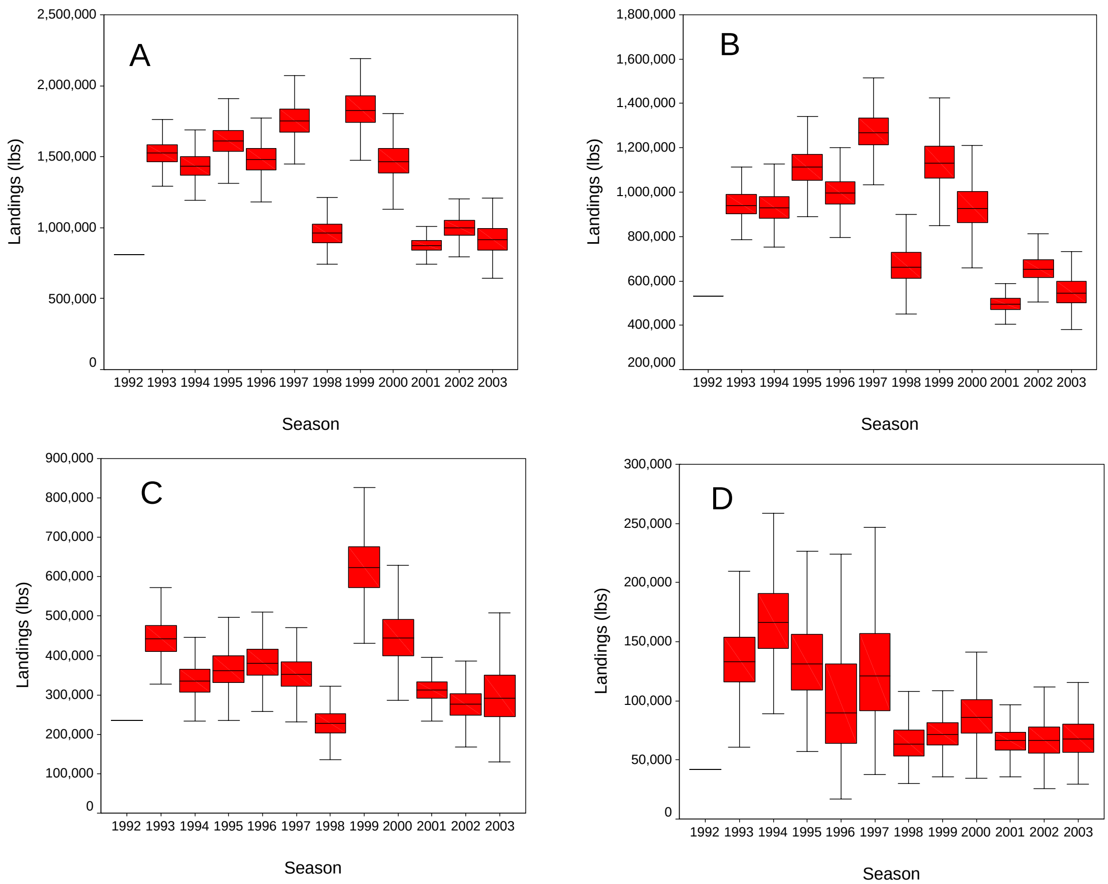
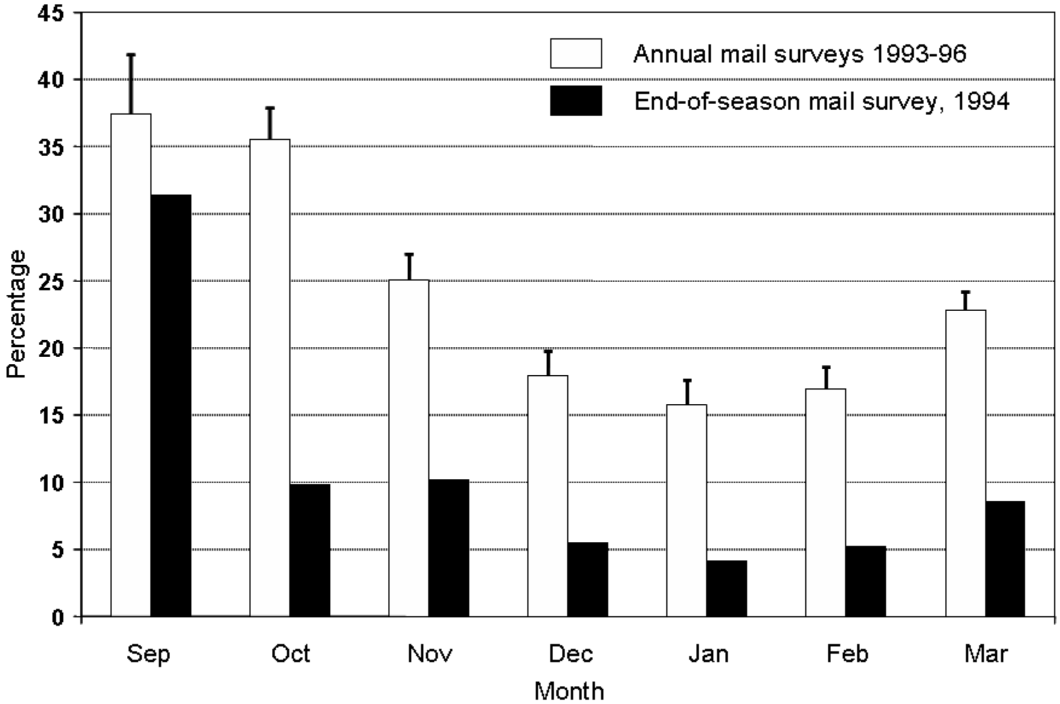


Figure 3.2.2 (7). Mean (±1SD) percentage of mail survey respondents that indicated they intended to fish after the Labor Day holiday, 1993-96, and the percentage of the 1994 end-of-season survey respondents that indicated they actually fished for lobster.



3.2.3 Special Recreational License

The number of license holders that possess the SRL has decreased progressively since the inception of the license in 1994 from a high of 498 to 306 by 2003. Landings reported by this group have ranged from 32,000 lbs to 75,000 lbs (Fig. 8), and have generally decreased along with the number of license holders. The largest proportion of fishing effort by this group each season has occurred prior to Labor Day (Fig. 9).

Figure 3.2.3 (8). Annual lobster landings reported by Special Recreational Lobster License (SRL) holders, 1994-2003.

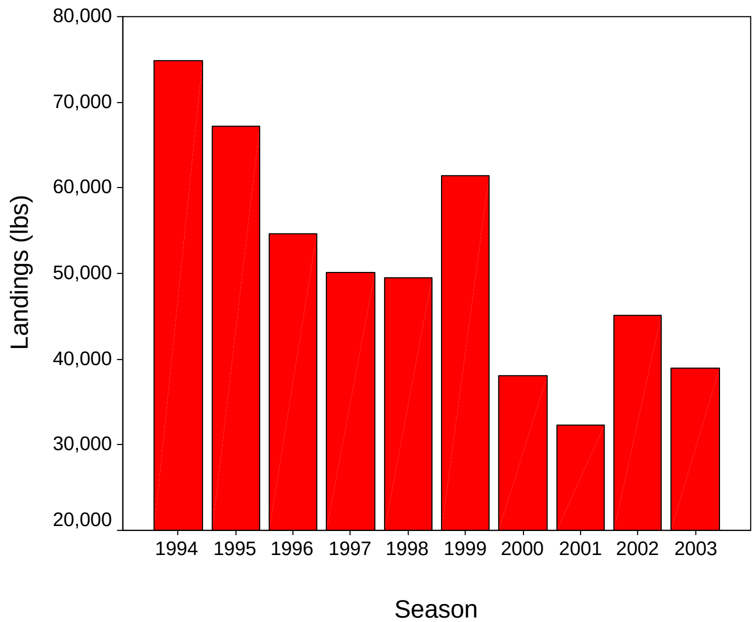
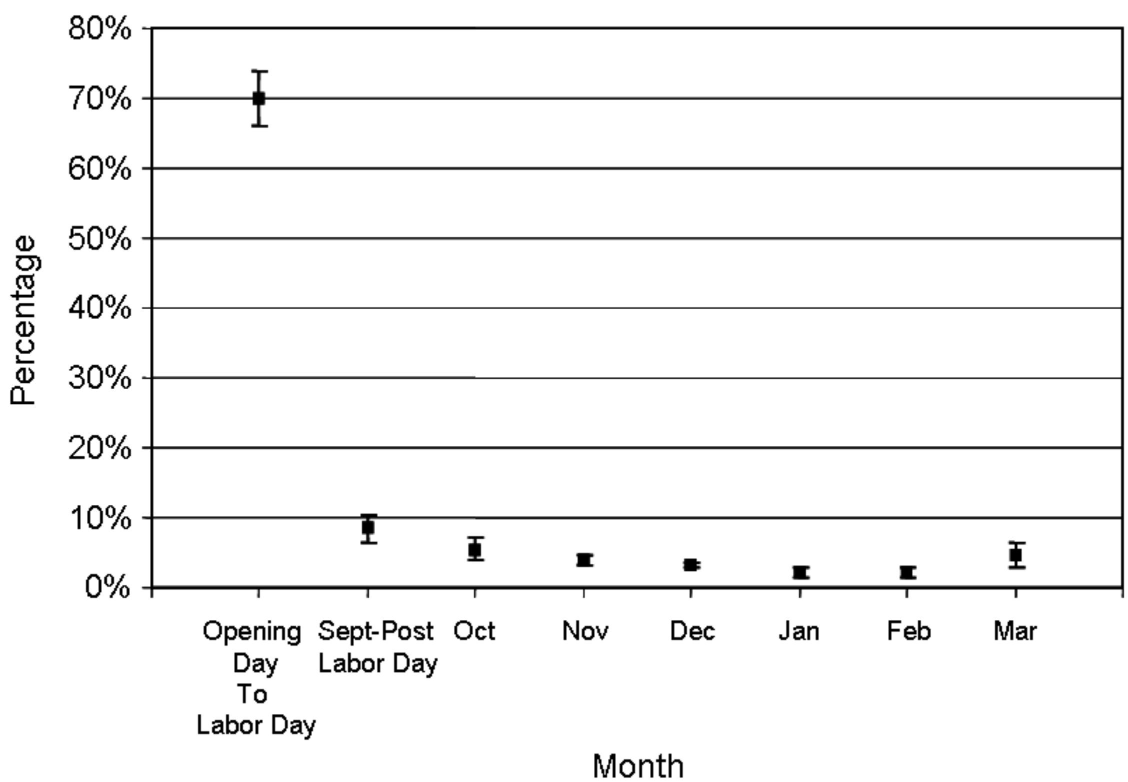


Figure 3.2.3 (9). Mean (±1SD) percentage of monthly lobster fishing trips reported by Special Recreational Lobster License holders, 1994-2003.



3.2.4 Recreational Discards

No information is available from the recreational fishery regarding discards

3.2.5 Recreational Catch-at-Age/Length

Recreational Catch-at-Length information is available for the 2002 Special Two-Day Sport Season and the first two weeks of the regular season in the Florida Keys. As described above, with the exception of that season, commercial catch-at-length data are used in the FWC's mail surveys to convert estimated lobster landings from numbers of lobsters into weight. This assumption is discussed in detail in the FWC Creel Survey section in the Fishery-Dependent Survey Data section of this document.

4.0 Fishery-Dependent Survey Data

4.1 Trip Interview Program

In 1984 the National Marine Fisheries Service (NMFS) and the Florida Department of Natural Resources Bureau of Marine Research, now the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute (FWC-FWRI) entered into a long term agreement to collect data from Florida's commercial marine fisheries to provide information to federal and state fishery managers. This agreement, the Federal-State Cooperative Statistics Agreement, created two programs, one, Florida Trip Ticket System, is designed to provide data from all commercial fishing landings throughout the state. The other program, the Trip Interview Program (TIP) is designed to collect data directly from fishermen as they land their catches. To acquire these data, contact the Trip Interview Coordinator at the Southeast Regional Science Center of the National Marine Fisheries Service.

Personnel (Port Agents) from the NMFS and FWC-FWRI are stationed at ports throughout Florida and visit commercial fishery landings sites to interview fishermen as they arrive to unload their catches. Port Agents interview vessel captains or members of the crew to obtain detailed information concerning the fishing trip and collect biological samples when appropriate. Although TIP was originally a quota-sampling program for selected finfish, from the start data were collected from spiny lobster fishing trips as well. Spiny lobsters were officially added to the species to be sampled in 1992.

Port Agents generally determine a site to sample by either calling ahead to see if boats are expected or going to various sites and waiting for fishermen to arrive. No attempt is made to use stratified random sampling methods. Samplers will however, refrain from sampling the same site time after time and attempt to sample at various geographical locations.

A typical TIP lobster fishing trip sample (interview) consists of meeting a fisherman as the catch is landed and asking a series of detailed questions about the fishing trip. Information gathered include, start and end dates of the trip, number of individuals in the crew (including the captain), number of days/hours at sea, and number of days/hours spent actively fishing. Vessel identification number, vessel name and length are recorded if available. Detailed information concerning fishing gear or gears used is collected, including what types of gear were used, how many were fished, for example how many traps were set or how many divers there were. How long the traps were in the water since the last pull or how many dives were made are also determined. Fishing area as defined by one-degree latitude and one-degree longitude square blocks is determined. More precise fishing locations are often obtained by dividing a block into four quadrants. Another method for determining more precise locations is to use geographic boundaries based on habitat (Figure 1.).

Biological sampling of spiny lobster catches is conducted by recording the species in the catch including any by-catch, landings weight of the catch, the price per pound and the number of trips made for the catch. A sample of the lobsters in the catch is obtained usually by requesting a portion be placed in a container that contains 30 to 40 pounds of whole lobster. If a catch is 50 pounds or less the entire catch is sampled. The portion to be sampled is chosen by selecting at random a container of lobsters as they are unloaded and placing them in the sample container. The sample is weighed and then the carapace length for each lobster is measured to the nearest millimeter and its sex is determined. Data collected are entered into a standard data entry program provided by the NMFS.

During the period 1985 to March 2004 there were 3,783 spiny lobster fishing trips sampled with 143,841 lobsters measured for carapace length and sexed. Of the 143,841 lobsters measured 84% were landed in Monroe County (Table 1.). Monroe County, Florida accounted for 3,443 (91%) of these trips. In Monroe County 94% of the trips sampled were trap catches while 80% of trips sampled from the northeast coast of Florida were dive catches. Gears other than traps and diving (various types of nets and hook and line) accounted for small percentages of trips sampled (Table 2.). The percentage of trips sampled per year has increased over the course of the program with a large increase in 1999 (Figure 2).

There is sufficient information in the data set currently available to me to discuss catch and effort after 1987. Average catch rates for two types of spiny lobster fishing gears can be calculated. Catch rates for the trap fishery vary widely because of multiple combinations of traps hauled, trap soak times and landings weights of the catches. Soak times vary over the course of the season and increase as the season progresses. Rates of from .01 pounds to just over 6 pounds of lobster per trap per fishing trip have been recorded. Adding soak time provides figures of .00001 to 0.46 pounds per hour. Converting catch rates to a 'standardized seven day soak', the range is 0.005 pounds to 48 pounds. Catch rates over time have increased except for 2001 and 2002 (Figure 3). Diver catch rates were calculated in pounds per hour per dive with a range of 0.0002 pounds to 0.7869 pounds (Figure 4.).

There were 75,355 males, 67,840 females and 646 unsexed lobsters measured from commercial spiny lobster catches from 1985 to 2004. The carapace length of lobsters in the commercial catch indicates that the fishery is heavily dependent on smaller lobsters (Figure 5.). Descriptive statistics by year and sex indicated that males were slightly larger than females and carapace length varied with out trend over time (Tables 3 and 4.). There were 141,034 lobsters measured with sufficient information to determine fishing regions (Florida east coast, north of lat 27N; Florida southeast coast, between lat 25N and 27N; Florida Keys, between 24N 82W and 24N and 80W; West of Key West, south of 25N and west of 82W; Florida west coast the west coast of Florida north of 25N. The largest lobsters were landed from dive catches from the east coast of Florida and the smallest from traps in the Florida Keys.

There is more detailed information available from samples taken in Monroe County (Florida Keys). In 1987 FWC personnel separated fishing area into 9 locations based on geographic divisions on both the ocean side and the bay (gulf) sides of the Keys. Fishing areas 1, 3, and 5 are on the bay (gulf) side if the Keys; Area 1 is north and east of the west end of Long Key, area 3 is between the west end of Big Pine Key and the west end of Long Key, area 5 is between the west end of Key West and the west end of Big Pine Key. Areas 2, 4, and 6 correspond to the same divisions on the ocean side of the islands. Area 7 is west of Key West to the Marquesas Keys. Area 8 is the waters around the Dry Tortugas, and area 9 is north of latitude 25N in the Gulf of Mexico. Unfortunately this data is not included in the TIP database but is available from FWC. National Marine Fisheries Service personnel began to separate fishing location into quadrants of latitude and longitude squares in 1992. These areas include the squares with lower right corners; 24N and 83W, 24N and 82W and 24N 81W. The quadrant numbers 1 and 2 indicate the northern sections west to east and quadrants 3 and 4 indicate the southern sections also from west to east. Examining data from samples taken by FWC personnel throughout the Keys indicates little difference in the size of lobsters landed except for those landed from landed from the Dry Tortugas (Figure 6.). Data from samples taken by NMFS personnel indicate little difference in the size of lobsters landed from the lower Keys. There are indications lobsters from quadrants 1 and 3 (western side of the lat – long block 24N 82W) may be larger than those from the eastern side (quadrants 2 and 4) (Figure 7.). Lobsters landed from the Dry Tortugas from all quadrants except quadrant 3 (lower right of the square) are similar in size and are larger than else where in the Keys (Figure 8.).

Data from the Trip Interview Program consists of accurate length measurements taken by trained personnel to information reported verbally by fishermen at the time of landing. Data concerning catch and sample weights are accurate, Port Agents weigh the samples taken and total catch weights are obtained at the time of landing. Data concerning fishing effort and location are obtained when interviewing fishermen and may be estimates of traps pulled or soak times. Data concerning fishing locations is generally accurate.

Several issues were observed in using the TIP data set. There appear to be errors in some carapace length measurements, carapace length measurements as small as 10 mm were observed. This could have been a result of using the wrong code for length measurements for example measuring in centimeters and using the code for measuring in millimeters. Some fishing areas appear to have been miscoded, for example fishing areas 739.0 and 740.0 are not shown on the fishing area map provided by FWRI. The number of these issues is small and could be resolved by having the relevant Port Agents check field data sheets and provide corrections where necessary.

Figure 4.1 (1). Map provided by Florida Fish and Wildlife Conservation Commission indicating fishing area codes to be used on trip tickets also used for reporting fishing locations for TIP interviews.

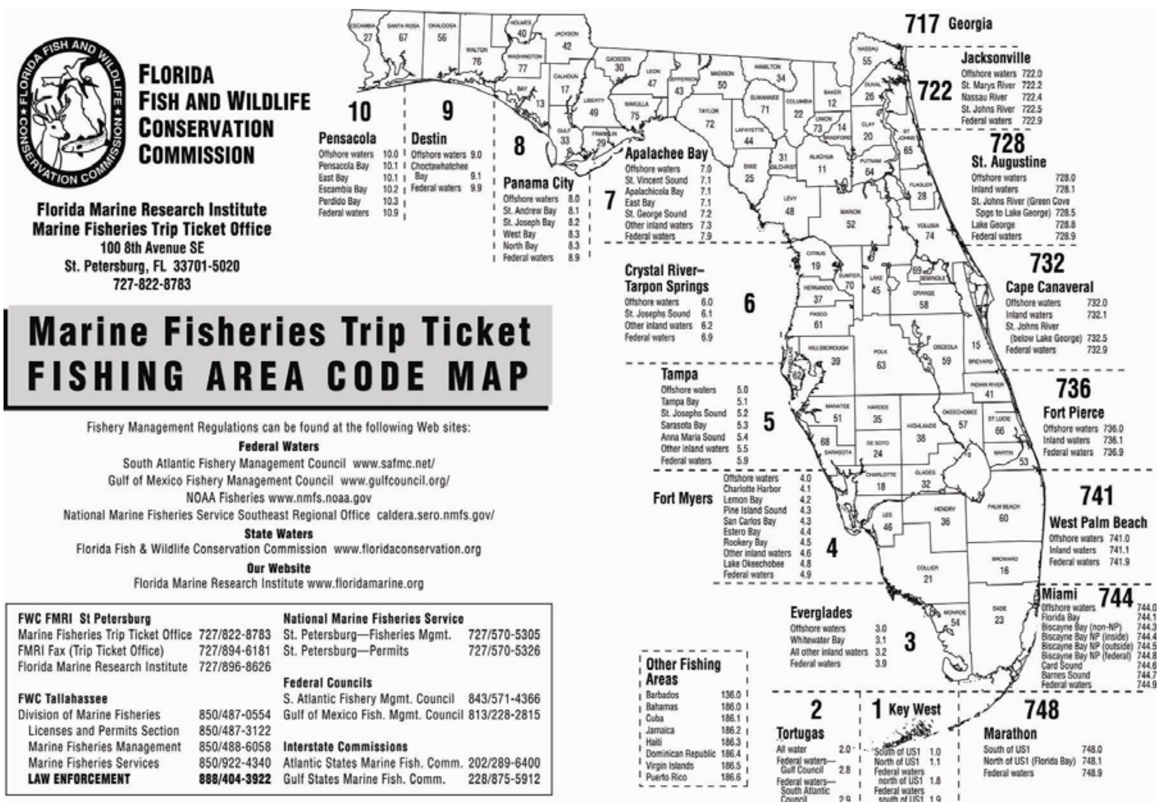


Figure 4.1 (2). Histogram of percentages of total commercial spiny lobster catches sampled by TIP.

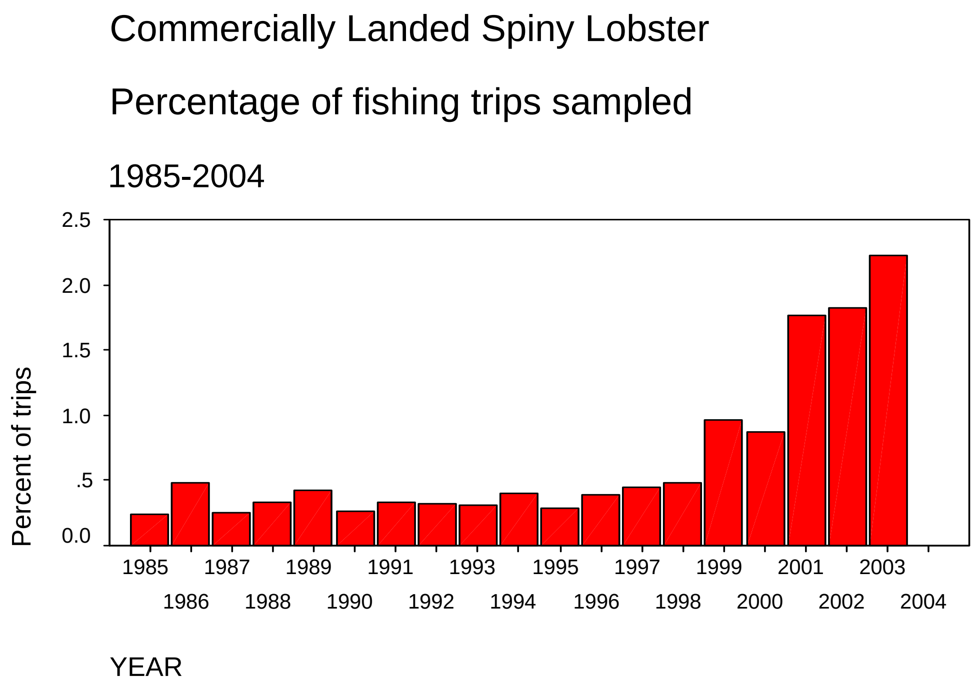


Figure 4.1 (3). Histogram of standardized catch rates of the spiny lobster trap fishery trips sampled by TIP. Standardized catch rates were calculated for each trip sampled by number of pounds landed by the number of traps pulled for that trip, the result was divided by the trap soak time in hours and then multiplied by 168 (the number of hours in a 7 day week). The calculated catch rates for each trip for each year were then averaged.

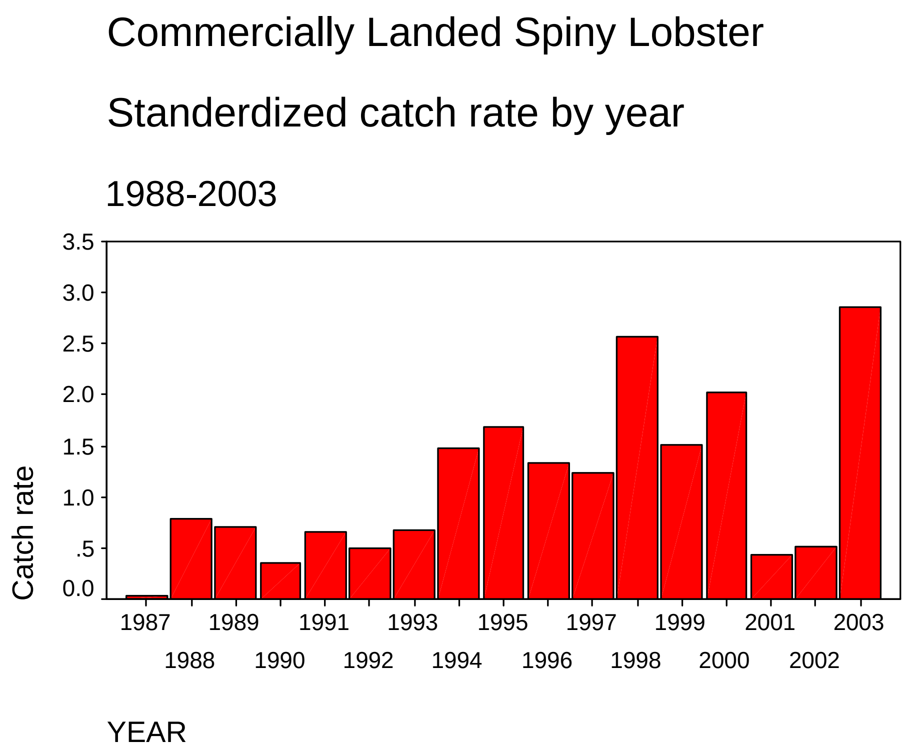


Figure 4.1 (4). Histogram of spiny lobster commercial dive trips sampled by TIP. Catch rates were calculated by dividing the number of hours fished by the catch weight to determine catch per hour. The calculated catch rates for each trip for each year were then averaged.

Commercially Landed Spiny Lobster

Diver catch rates

1988-2003

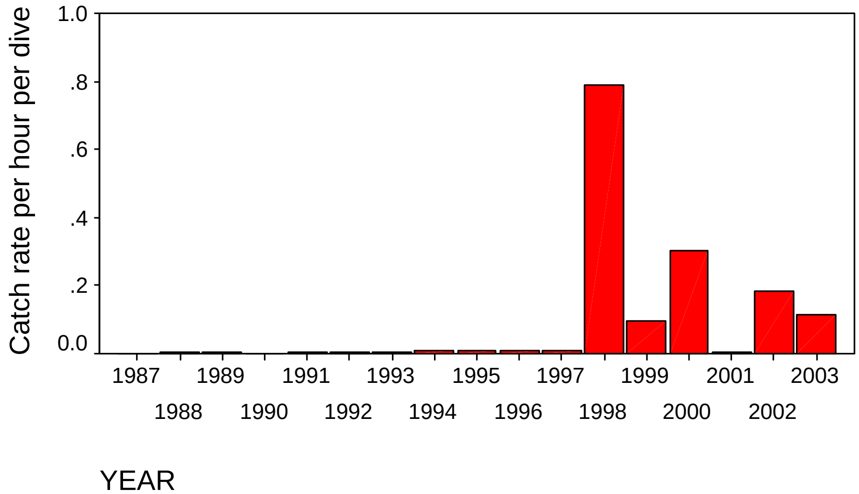


Figure 4.1 (5). Length frequency histogram of spiny lobsters in commercial catches sampled by the TIP program 1985 - 2004.

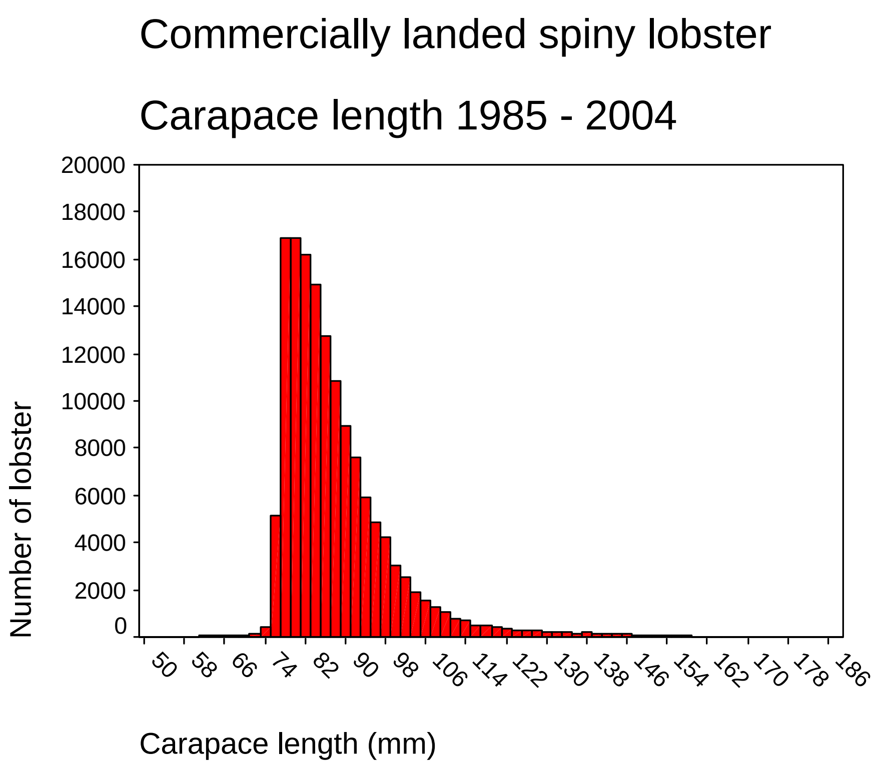


Figure 4.1 (6). Box and whisker plots of carapace lengths of spiny lobsters sampled from commercial catches by FWC personnel 1987 – 2004. Boxes indicate the interquartile range, which includes 50% of carapace length values for each region. Whiskers extend from the boxes and represent highest and lowest values at the 95% confidence level, excluding outliers. Lines in the boxes indicate the median carapace length values for each region.

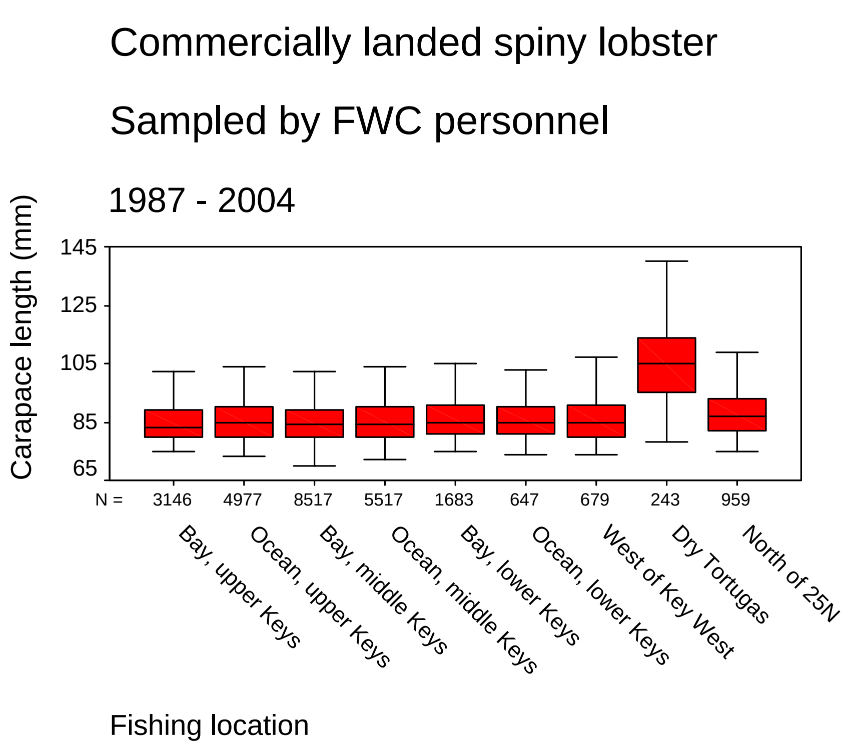


Figure 4.1 (7). Box and whisker plots of carapace lengths of spiny lobsters sampled from commercial catches by NMFS personnel 1992 – 2004. Boxes indicate the interquartile range, which includes 50% of carapace length values for each quadrant. Whiskers extend from the boxes and represent highest and lowest values at the 95% confidence level, excluding outliers. Lines in the boxes indicate the median carapace length values for each quadrant.

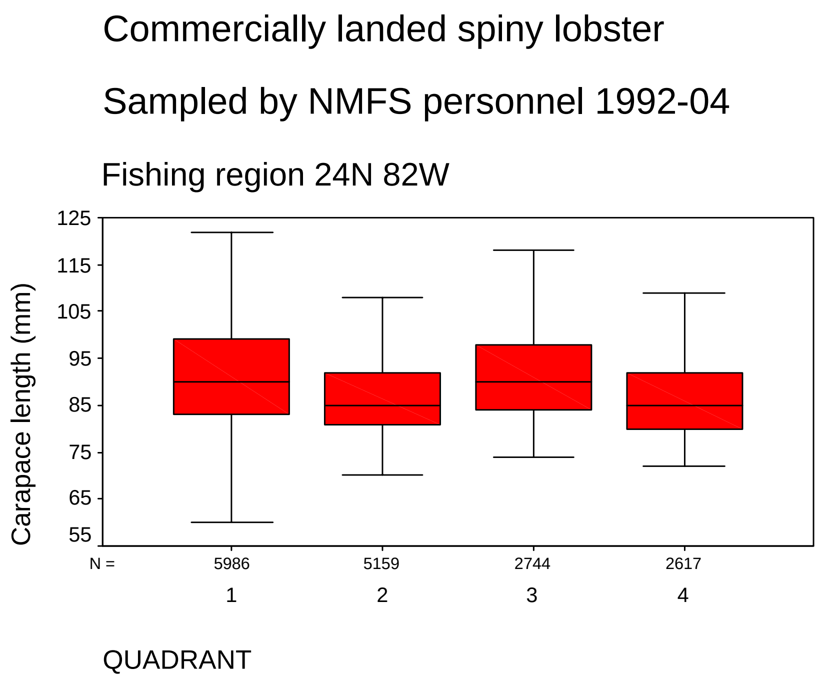


Figure 4.1 (8). Box and whisker plots of carapace lengths of spiny lobsters sampled from commercial catches by NMFS personnel 1992 – 2004 from the Dry Tortugas. Boxes indicate the interquartile range, which includes 50% of carapace length values for each quadrant. Whiskers extend from the boxes and represent highest and lowest values at the 95% confidence level, excluding outliers. Lines in the boxes indicate the median carapace length values for each quadrant.

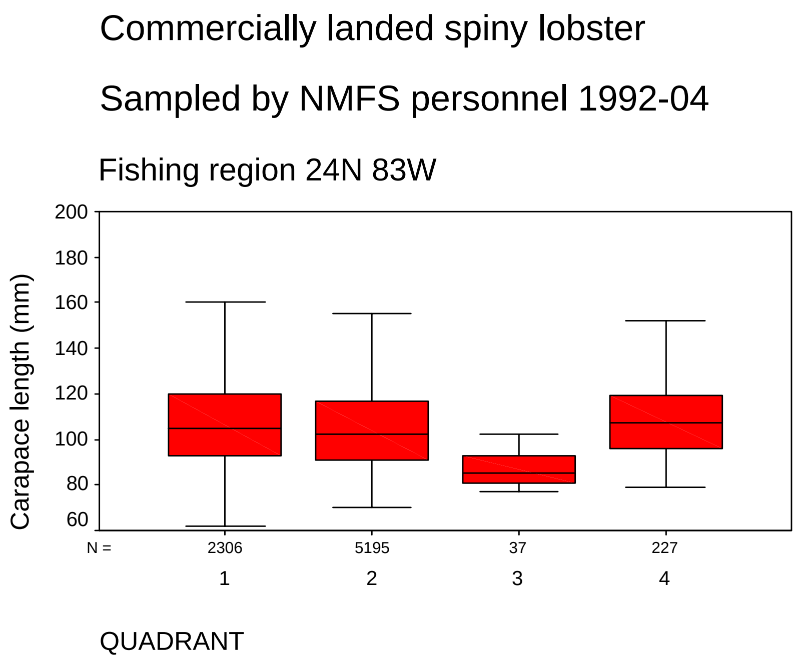


Table 4.1 (1). Number of lobsters sampled from commercial catches by region and gear from 1985 to 2004. Regions were determined from reported fishing areas, The Florida Keys were determined to be the areas north and south of the Keys island chain east of longitude 82W; West of Key West was determined to be the area west of longitude 82W; Southeast Florida was determined to the east coast of Florida between latitude 25N and 27N; Northeast Florida was determined to be the east coast of Florida north of latitude 27N; and the west coast of Florida was determined to be the west coast of Florida north of latitude 25N.

	Region					
	FL Keys	West of Key west	Southeast FL	Northeast FL	West Coast FL	Not recorded
Gear						
Traps	90,858	32,435	6,844	0	138	3,143
Diving	4,688	2,757	1,265	732	0	166
Other	382	133	240	2	0	1
Unknown	27	0	0	0	0	29
Total	95,955	35,325	8,349	734	138	3,339

Table 4.1 (2). Number of commercial spiny lobster fishing trips sampled by TIP by region and gear from 1985 to 2004. Regions were determined from reported fishing areas, The Florida Keys were determined to be the areas north and south of the Keys island chain east of longitude 82W; West of Key West was determined to be the area west of longitude 82W; Southeast Florida was determined to the east coast of Florida between latitude 25N and 27N; Northeast Florida was determined to be the east coast of Florida north of latitude 27N; and the west coast of Florida was determined to be the west coast of Florida north of latitude 25N.

	Region					
	FL Keys	West of Key West	Southeast FL	Northeast FL	West Coast FL	Not recorded
Gear						
Traps	2,410	743	219	15	4	102
Diving	144	59	43	2	0	12
Other	12	133	9	2	0	1
Unknown	2	5	0	0	0	3
Total	2,568	940	271	19	4	118

Table 4.1 (3). Descriptive statistics of male spiny lobsters sampled by TIP from commercial catches by year. Carapace length (CL) measured in millimeters. Some very small lobsters reported may be due to data entry errors.

Year	Number	Mean CL	Std. Error	Median CL	Minimum CL	Maximum CL
1985	1,051	87.6	0.257	86	73	127
1986	2,086	88.6	0.229	87	69	164
1987	1,456	88.6	0.241	87	74	133
1988	3,158	85.9	0.015	84	69	159
1989	3,624	88.6	0.163	87	75	161
1990	1,951	88.0	0.264	85	75	161
1991	2,869	89.7	0.232	87	71	170
1992	2,973	90.2	0.383	86	*10.6	180
1993	2,552	94.1	0.425	86	71	209
1994	3,581	88.8	0.839	85	60	185
1995	2,436	93.7	0.336	89	73	183
1996	3,201	87.6	0.190	85	72	180
1997	3,889	87.4	0.168	85	70	176
1998	3,058	89.0	0.194	87	*11.8	155
1999	6,767	88.1	0.125	86	70	174
2000	5,056	89.2	0.156	86	73	172
2001	7,241	91.7	0.179	86	*8.0	196
2002	7,691	90.0	0.149	86	*10.5	194
2003	9,538	89.2	0.116	87	*10.0	190
2004	1177	87.9	0.362	84	75	170

Minimum CL measurments with an * are possible data entry errors.

Table 4.1 (4). Descriptive statistics of female spiny lobsters sampled by TIP from commercial catches by year. Carapace length (CL) measured in millimeters. Some very small lobsters reported may be due to data entry errors.

Year	Number	Mean CL	Std. Error	Median CL	Minimum CL	Maximum CL
1985	877	83.5	0.221	82	70	119
1986	1,967	84.7	0.176	83	69	140
1987	1,500	84.4	0.189	83	70	123
1988	2,728	83.1	0.119	82	63	134
1989	3,523	84.6	0.118	83	70	138
1990	1,809	85.1	0.220	83	72	146
1991	2,536	86.0	0.206	83	50	152
1992	3,103	86.1	0.248	84	*22.0	145
1993	2,049	88.3	0.317	83	66	165
1994	3,060	85.5	0.180	83	58	175
1995	2,388	88.1	0.241	85	72	165
1996	3,028	83.9	0.145	82	66	147
1997	3,040	83.5	0.142	81	72	138
1998	2,714	85.0	0.160	83	70	152
1999	5,324	84.4	0.108	82	70	156
2000	4,565	85.7	0.146	83	*8.5	155
2001	6,918	87.5	0.134	84	69	160
2002	6,914	87.0	0.130	84	70	151
2003	8,586	85.8	0.099	83	70	177
2004	1211	86.4	0.261	84	71	132

Minimum CL measurments with an * are possible data entry errors.

4.2 FWC Observer Program

The broad objectives of the program were to obtain length frequency measurements of both legal and undersized spiny lobsters captured in commercial lobster traps for different localities and months of the fishing season, in order to detect any changes in the status of the fishery and to monitor the effectiveness of management regulations. Specific objectives of the program included 1) providing details of the population structure within the selection range of the traps, 2) provide information on the location, time , and size of breeding, 3) develop and index of juvenile abundance, 4) evaluate bycatch in the fishery, 5) document fishery practices like trap placement, trap deployment period, and use of undersized lobsters as bait (Figure 1), and 6) measure catch rates. The onboard monitoring program is the only monitoring program that directly measured the abundance of juvenile lobsters, bycatch from the trap fishery, and catch rates.

Monitoring of commercial catches began in August 1993 and continued through March 2000. In the first year of monitoring, the 1993-94 fishing season, 4 observer trips were made in each month in each of 7 areas in the Florida Keys. In subsequent fishing seasons, 2 trips per month were completed. Observations regularly occurred in 7 sampling regions in the Florida Keys: Upper Keys-Atlantic, Florida Bay, Middle Keys-Atlantic, Middle Keys-Gulf, Lower Keys-Atlantic, Lower Keys-

Gulf, and the Marquesas. Occasional samples were also collected in Atlantic waters near Miami. In 1995-96 samples were collected monthly in the Dry Tortugas. The onboard monitoring program entails staff accompanying commercial lobster trap fishers as they conduct their normal fishing operations. Fishers were chosen from a pool of volunteers obtained through mail survey correspondence. After the first year of sampling schedule was revised, we attempted to sample a monthly total of 300 traps per area from at least 2 different fishers during the open fishing season. Contents of approximately 150 lobster traps were recorded on each fishing trip. Sampling frequency was determined each day by the number of traps the captain planned to pull. For example, if the captain planned to pull 300 traps, every other trap was sampled. When a trap was sampled, all lobsters and bycatch in that trap were placed in a plastic fish basket. Sex and size of each lobster and the reproductive condition of females were recorded. Size was reported as carapace length (CL) measured to the nearest millimeter using dial calipers. For lobsters measuring 76-76.5 mm, CL was recorded to the nearest 0.1 mm in order to retain information relative to the legal size limit of 76.2 mm (3 in). Reproductive condition of females was recorded as presence of spermatophores, eroded spermatophores, or eggs. Dead lobsters were sexed and measured when possible. Bycatch was identified and enumerated, and the size of fish were recorded to the nearest inch, and stone crab claws were graded as medium, large, or jumbo following the commercial standards. Stone crabs possessing sub-legal claws were recorded as number of individuals with sub-legal claws. Encrusting and fouling organisms were not recorded as bycatch. The location of each trap was recorded to the nearest 1-minute latitude and longitude. Trap construction, soak time, and bait were also recorded.

The subsample of fishermen observed attempted to follow a stratified random design with equal numbers of samples in each area and month. In 1993-94, the survey included 119 different fishermen. This methodology resulted in approximately 20% of the trips resulting in little or no data collection because of fishing equipment malfunction or other problems. Surveys in subsequent fishing seasons maintained the equal sampling effort in each region and month but we repeatedly sampled a limited group of fishermen that had more consistent fishing habits.

The database associated with this project has been used to describe and evaluate bycatch from different trap types, to describe trap fishing methods including baiting practices and soak times, to estimates the mortality rate of undersized lobsters used as bait, to compare regional catch rates, and to calibrate stock assessment estimates. The fishermen observed during this program were not a random subsample of the fishery and generally have catch rates in the upper 25% of those observed for the fishery. Table 1 and 2 indicate the number of traps that were observed in each month and fishing area. The design of the study generally allowed for collection of a high number of observations of traps, but the traps were usually in a small area and not representative of the entire month and thus did not adequately reflect the variability of catch rates for traps in that area for that tie period.

The mean carapace length for legal-sized lobsters does not vary between locations or seasons in the Keys (Table 3). Carapace length does appear to fluctuate west of Key West. The average length of lobster captured in the fishery is within one molt of the legal minimum size. Since lobsters may molt several times each year this may indicate that fishing pressure is very high. The average size at capture may also be essentially fixed, because of the high percentage of lobsters that are captured immediately upon reaching legal size.

The mean catch per trap appears to vary without trend between areas and months (Table 4 and 5). These results are inconsistent with the relatively rapid reduction in monthly landings reported in trip tickets. This inconsistency between catch is presumably highly influenced by altering the trap deployment time. As catch rates per day diminish, trap deployment periods become longer and the catch rate per trip or trap pull remains stable. The lack of a trend in this important statistic may also be a function of sampling many traps that belong to a few fishermen each trip. The amount of variability within one fishermen's traps would be expected to be less than all traps in a specific area at a specific time. The mean catch of undersized lobsters per trap increased as the number of traps in the fishery decreased while the total number of undersized lobster confined in trap remained unchanged (Figure 1). This is consistent with fishermen's contentions that undersized lobsters are a valuable commodity and the demand for undersized lobster exceeds their supply. This also raises the cautionary note for using fishery dependent data as a measure of abundance. The number of undersized lobsters in traps was affected by changes in the number of traps available to the fishery and not a change in lobster abundance.

Table 4.2 (1). Number of traps sampled each month.

Fishing Season	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1993-94	2210	3211	3257	2514	2904	2479	2717	2991
1994-95	1834	1501	1677	1349	1570	1508	1086	974
1995-96	2304	2808	2344	2209	2107	1942	1618	1538
1996-97	1996	1647	1746	1424	1482	1460	1124	1467
1997-98	1727	1678	1601	1315	1526	1107	1475	1070
1998-99	1861	803	1038	1609	1512	962	875	967
1999-2000	862	701	131	351	706	697	924	354
2000-01	1224	1601	1119	901	840	956	705	911

Table 4.2 (2). Number of traps sampled in each fishing area.

Fishing Season	Florida Bay	Upper Keys Ocean	Middle Keys Gulf	Middle Keys Ocean	Lower Keys Gulf	Lower Keys Ocean	Marquesas Gulf	Marquesas Ocean	Tortugas
1993-94	2625	3455	4104	3141	3133	3127	2698	*a	
1994-95	1686	2083	2385	2241	*b	*c	1403	1701	
1995-96	1565	4604	2702	1777	*b	*c	1451	1812	2959
1996-97	1624	2209	2097	2159	*b	*c	2138	1583	536
1997-98	1573	1930	2212	2722	*b	*c	1883	1179	
1998-99	1405	2075	1507	1652	*b	*c	1618	1370	
1999-2000	805	634	1009	1156	*b	*c	735	200	145
2000-01	1051	1829	1641	1510	*b	*c	1054	1118	54

*a Included in Marquesas Gulf
*b Included in Middle Keys Gulf
*c Included in Middle Keys Ocean

Table 4.2 (3). Mean carapace length for lobsters in each fishing area and fishing season.

Fishing Season	Florida Bay	Upper Keys Ocean	Middle Keys Gulf	Middle Keys Ocean	Lower Keys Gulf	Lower Keys Ocean	Marquesas Gulf	Marquesas Ocean	Tortugas
1993-94	83.0	83.8	82.9	83.4	83.8	82.6	85.5	.	.
1994-95	83.2	85.6	86.0	83.9	.	.	88.1	85.3	.
1995-96	83.7	84.5	84.9	83.8	.	.	88.8	89.2	93.4
1996-97	82.1	85.2	83.8	82.4	.	.	85.3	86.8	95.0
1997-98	82.8	83.0	85.0	82.6	.	.	85.8	83.6	.
1998-99	82.7	84.5	84.3	83.2	.	.	85.8	85.1	.
1999-2000	82.0	81.8	86.6	83.4	.	.	85.3	82.3	100.3
2000-01	83.0	84.1	83.4	83.0			86.3	83.3	83.3

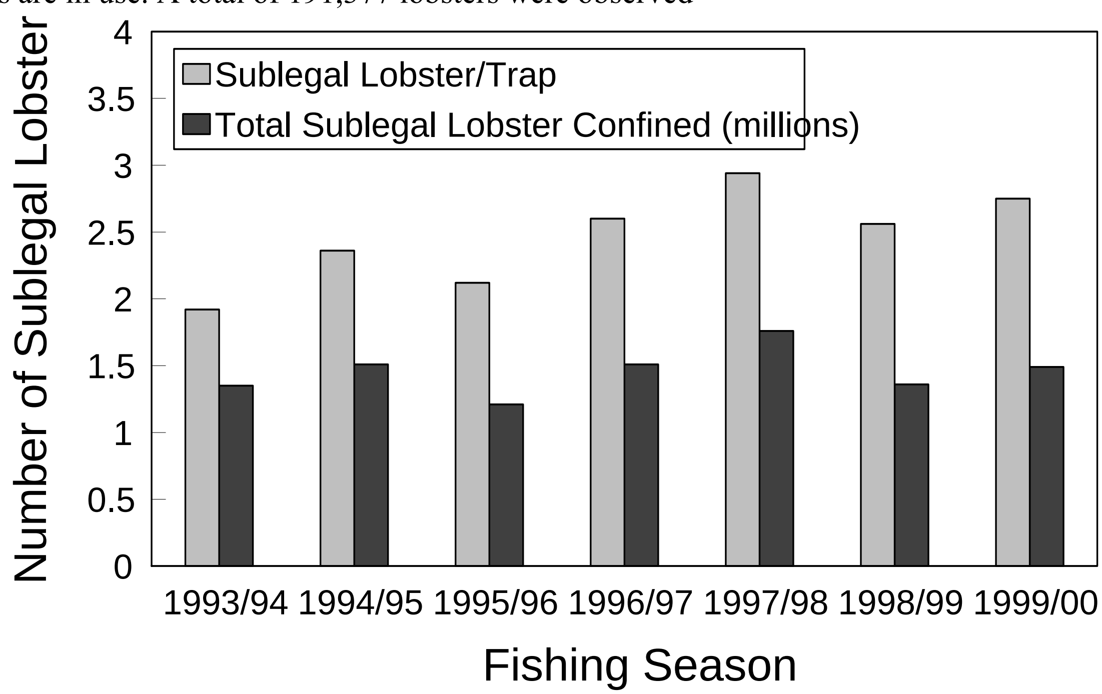
Table 4.2 (4). Mean lobster catch (grams) per trap observed in each month of each fishing season.

Fishing Season	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1993-94	415	434	425	321	318	308	235	372
1994-95	1058	753	816	783	424	417	581	297
1995-96	800	699	944	631	431	505	381	478
1996-97	861	613	798	988	596	357	304	269
1997-98	731	688	726	765	739	770	565	515
1998-99	750	778	1187	676	478	337	275	443
1999-2000	1335	1463	2260	962	931	481	345	1031
2000-01	535	599	644	378	307	506	227	507

Table 4.2 (5). Mean lobster catch (grams) per trap observed in each area for each fishing season.

Fishing Season	Florida Bay	Upper Keys Ocean	Middle Keys Gulf	Middle Keys Ocean	Lower Keys Gulf	Lower Keys Ocean	Marquesas Gulf	Marquesas Ocean	Tortugas
1993-94	316	520	287	277	312	321	475	.	.
1994-95	381	923	586	471	.	.	807	916	.
1995-96	438	662	491	507	.	.	859	799	676
1996-97	300	1001	573	469	.	.	807	528	363
1997-98	427	789	583	637	.	.	843	969	.
1998-99	331	756	575	528	.	.	777	749	.
1999-2000	800	645	880	809	.	.	1325	1479	2189
2000-01	339	534	295	369	351	806	643	626	192

Figure 1. The average number of sublegal-sized lobsters (60 to 76.1 mm carapace length lobsters) per trap and the total number of sublegal-sized lobster confined when all allowable traps are in use. A total of 191,377 lobsters were observed



4.3 Biscayne National Park Creel Survey

Located south of Key Biscayne and north of Key Largo, Biscayne National Park (BNP) encompasses an area of 173,000 acres (~270 square miles), of which 95% is marine (Fig. 1). In its oceanside component, BNP contains an extensive network of continuous and patch reefs interspersed with seagrass and sand beds (Fig. 2). These habitats support abundant lobster populations, fed via nursery production in the protected waters of Biscayne Bay, where lobster harvest is prohibited.

Since the origin of the two-day recreational sport season in 1987, BNP employees and park volunteers have conducted creel interviews with parties participating in the event (note: interview data from 1992 are missing). During this time, the park has conducted 3,498 interviews, and measured and sexed more than 49,000 lobsters.

4.3.1 Methods/Information Collected

Each year, interview teams are dispatched to Black Point and Homestead Bayfront marinas, both located in Homestead, FL (see Fig. 1). Interview teams arrive on site at ~ 0900h, and continue interviews until ~ 1630h. Interviews occur both days of the sport season.

The interviewers occur as follows: as a boat returns to the dock, interview teams approach the vessel, introduce themselves as BNP representatives, and state the purpose of the data collection efforts. The interview team then asks the captain if he/she is willing to participate. If so, 1-2 team members board the vessel to assess the lobster catch, and convey the size and sex of each lobster on board to the data recorder (as appropriate, other information is collected, including notes of gravid females). At the same time, the data recorder begins collecting trip information from the captain. The following trip information is collected:

- # of people lobstering
- # hrs spent lobstering
- Area fished (corresponding to a gridded map)
- GPS utilized?
- Familiar location?
- Method used (scuba, hookah, snorkel, bully net, etc.)
- Area of residence
- # of times anchored (to gain insight on potential anchor-related damage to the reef tract / patch reefs)

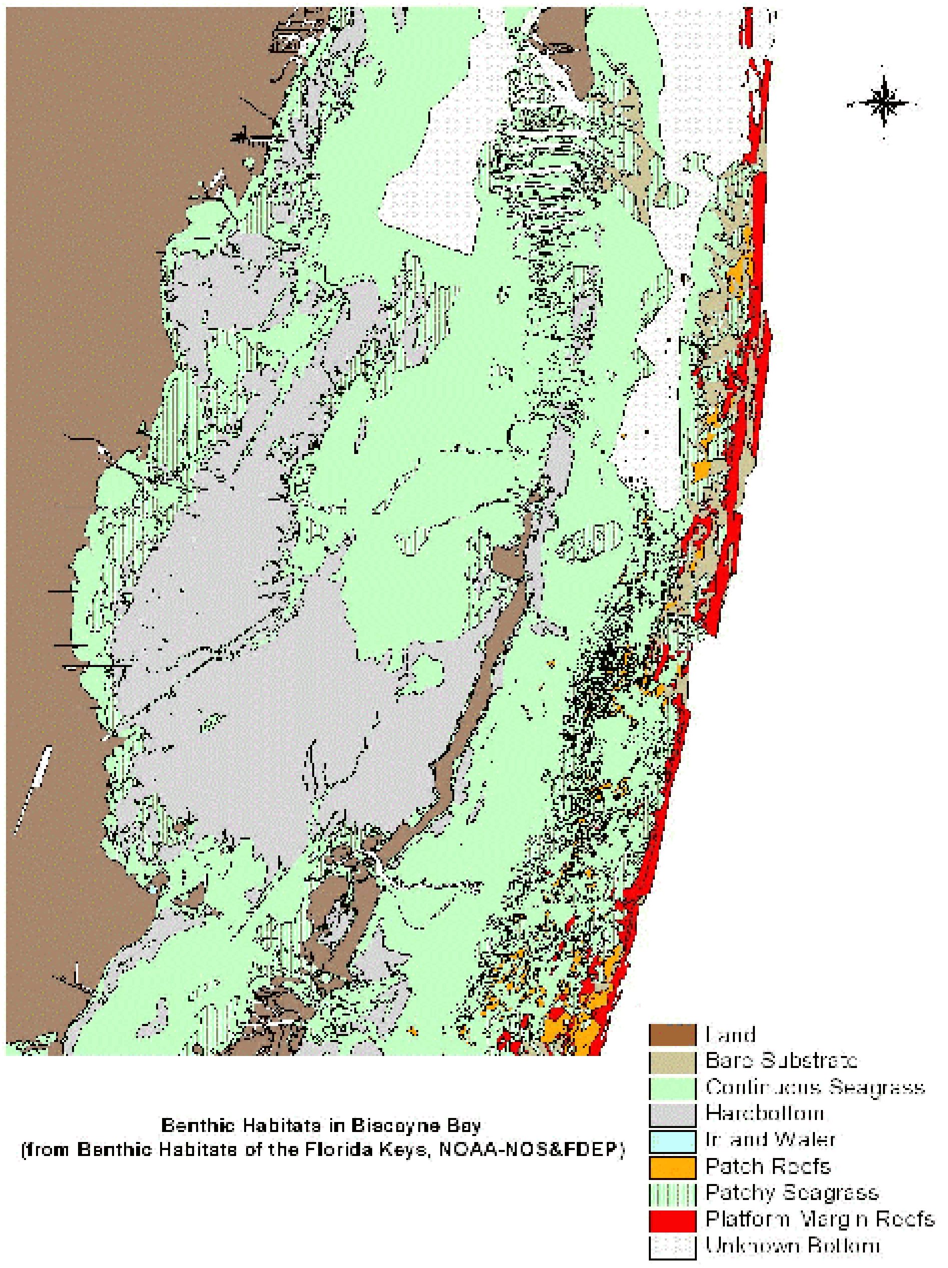
4.3.2 Trends

Analyses of interview data show an increase in CPUE (catch per trip, standardized by # of participants and hours fished per trip) from 1987 to 1999, and a subsequent decrease from 2000 to present (Fig.3). No significant trends are evident in mean size of catch (Fig. 4) or the proportion of the catch that is male versus female (Fig. 5).

Figure 4.3 (1).

MIAMI
KEY BISCAYNE
836
826
874
997
41
1
0
10 Kilometers
0
10 Miles
Biscayne Bay
Florida's Turnpike
821
BISCAYNE NATIONAL PARK
ATLANTIC OCEAN
EVERGLADES NATIONAL PARK
Homestead
Florida City
SW 137 Avenue
Convoy Point Visitor Center
SW 328 Street
9336
FLORIDA KEYS NATIONAL MARINE SANCTUARY
905A
905
Key Largo
JOHN PENNEKAMP CORAL REEF STATE PARK
KEY LARGO NATIONAL MARINE SANCTUARY
To Key West

Figure 4.3 (2).



Benthic Habitats in Biscoyne Bay
(from Benthic Habitats of the Florida Keys, NOAA-NOS&FDEP)

Figure 4.3 (3).

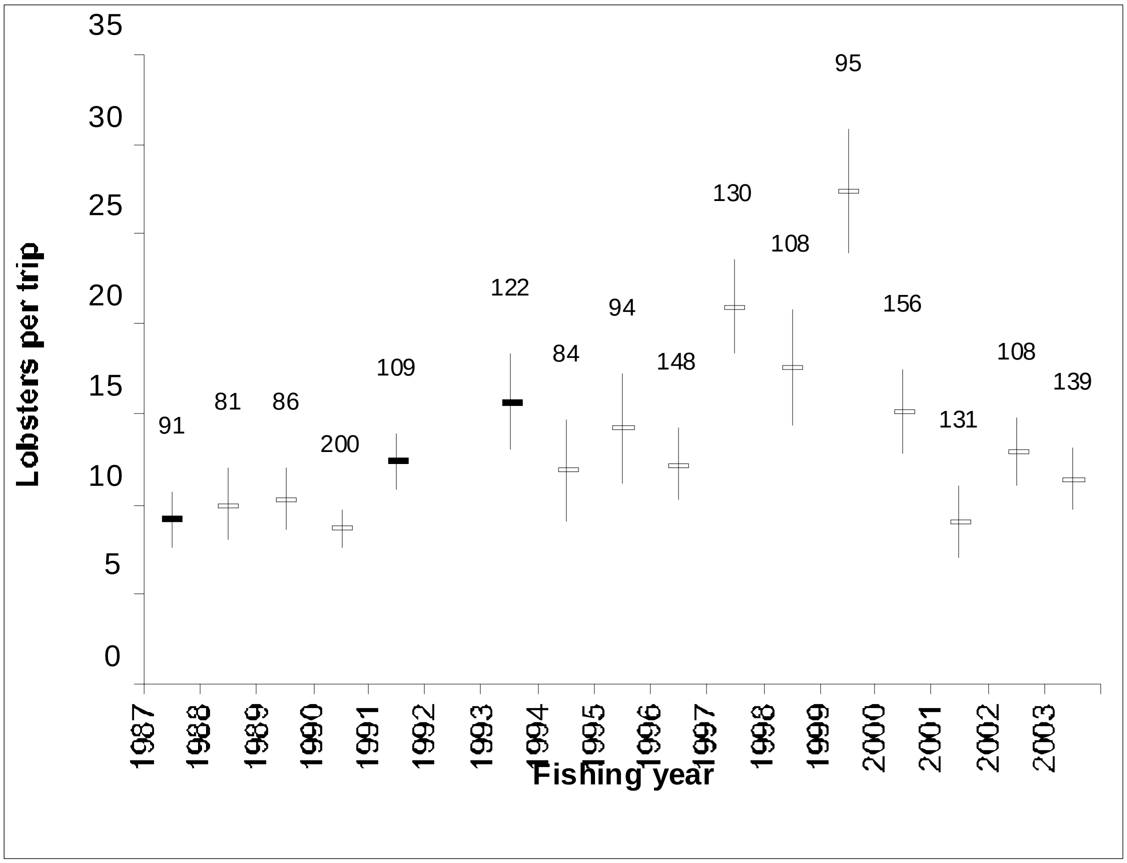

35
30
25
20
15
10
5
0
Lobsters per trip
91
81
86
200
109
122
84
94
148
130
108
95
156
131
108
139
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Fishing year

Figure 4.3 (4).

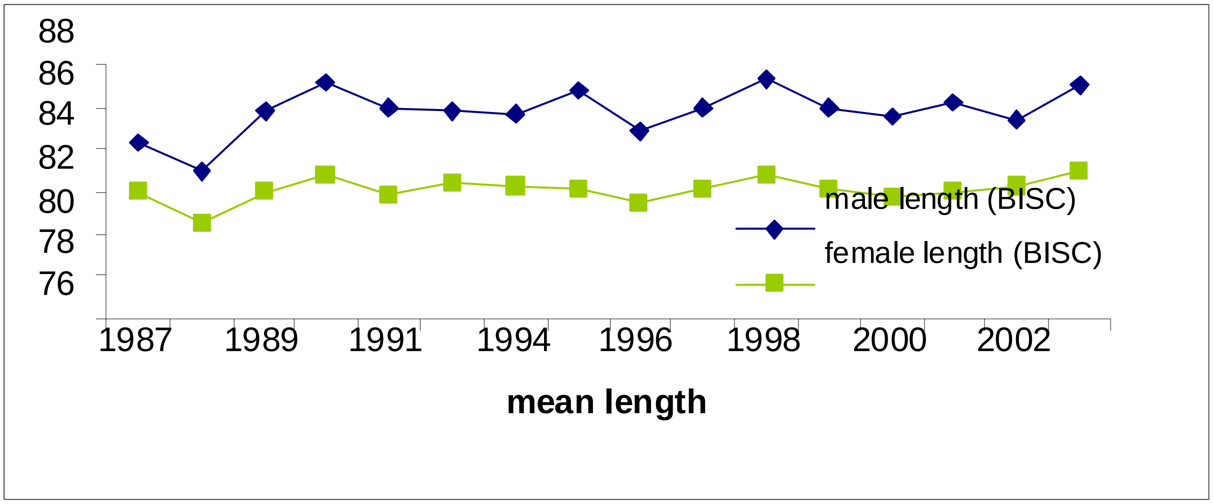
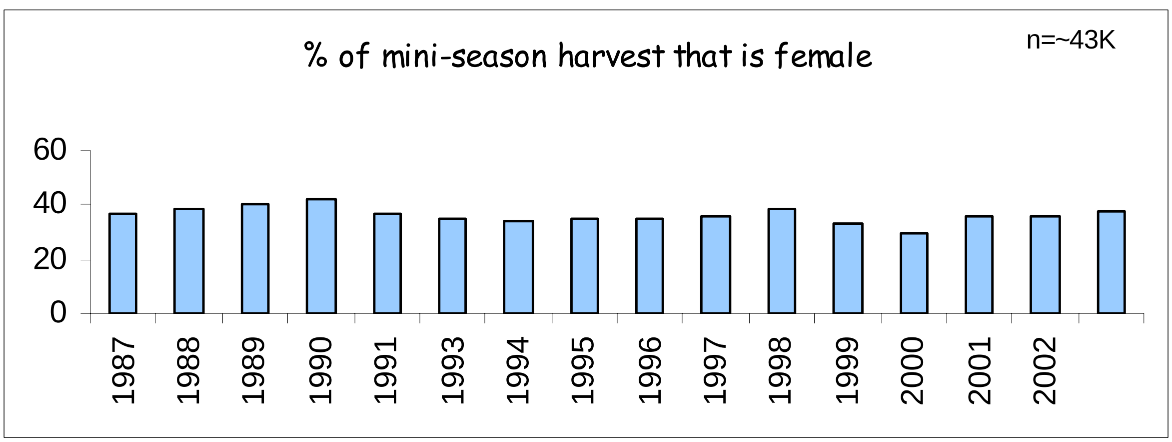


Figure 4.3 (5).



4.4 FWC Creel Survey

The Florida Fish & Wildlife Conservation Commission's (FWC) Florida Marine Research Institute (FMRI) conducted an intercept survey of recreational lobster fishers in the Florida Keys during the 2002 Special Two-Day Sport Season and during the first two weeks of the 2002/03 regular lobster fishing season. The primary objective of this study was to collect information on lobster landings, effort, and fisher demographics that could be compared to similar data collected by mail surveys of recreational lobster permit holders. Because the FWC does not collect length-frequency data from recreational lobster landings in the Florida Keys, similar data collected from commercial lobster landings are used to convert recreational landings derived from mail surveys, which estimate landings as numbers of lobsters, to an estimate of weight. It has been assumed that was no difference in the size structure of the lobsters landed by each fishery. Length-frequency data collected during the intercept survey was directly compared to those collected from the commercial fishery over the same time period to evaluate the validity of this assumption.

A total of 304 interviews of recreational lobster fishers were conducted during the Special Two-Day Sport Season. Those data were compared to 240 responses received from mail survey recipients who fished for lobster in Monroe County during the Special Season. No differences in lobster fishing experience, which potentially could directly influence CPUE, between mail survey respondents and those that participated in the creel survey ($G = 0.423$; $df = 1$; $P = 0.515$). However, fishing party CPUE estimated from the mail survey was significantly higher than that of the intercept survey on both days of the Special Two-Day Season (Figure 1). These differences were evaluated further using multiple regression and five variables that potentially affected daily lobster catch rates were modeled: the survey type (*i.e.,* creel or mail survey), the residence area of the fisher (*i.e.,* a local fisher vs. a visitor), the number of people in the fishing party, the fisher's lobster fishing experience, and fishing effort (the number of hours the fishing party fished) (Table 1). Despite local residents being underrepresented in the intercept survey, the residence area of the fisher did not contribute significantly to the model on Wednesday's catch rates, nor did fishing effort. The three remaining variables collectively accounted for approximately half of the observed variation in the model ($R^2_{adj} = 0.460$). Of those, the size of the fishing party overwhelmingly explained most of that variation (62%). Fishing experience accounted for an additional 18%; survey type was marginally significant, and accounted for only 8% of the explained variation. Similarly, multiple regression identified three variables that had effects upon Thursday's fishing party catch rate: number of people in the fishing party, fisher experience, and fishing effort, but those variables only explained only about 36% of the variation ($R^2_{adj} = 0.362$). No difference between survey types was detected, but again, the number of people in the fishing party accounted for the largest proportion of the explained variation (53%). The FWC concluded that the differences in catch rates during the Special Season was the result systematic bias in the intercept survey because it primarily targeted points of fishing vessel entry and exit frequented by small fishing vessels, and underrepresented fishing parties from comparatively larger fishing vessels. Individual fisher CPUE did not differ between survey methods on either day of the season (Day 1: MS = 7.146; F = 0.298; $P = 0.585$, Day 2: MS = 51.362; F = 2.972; $P < 0.086$, 1-factor ANOVA) (Fig. 2).

A total of 445 creel surveys were completed during the first two weeks of the regular lobster fishing season and compared to the responses of 215 mail survey respondents that fished in the Florida Keys. As with the Special Season Survey, no differences in lobster fishing experience between mail survey respondents and those that participated in the creel survey were detected ($G = 1.546$; $df = 1$; $P = 0.214$). No differences were detected in either fishing party or individual lobster catch rates between the two survey types (Fishing Party: MS = 237.943; F = 1.728; $P = 0.189$, Individual: MS = 3.688; F = 0.083; $P = 0.774$; 1-factorANOVA) (Fig 3).

During the creel survey, 1,174 lobsters landed by the recreational fishery ranging in size from 69 to 116 mm carapace length (CL) (± 1 s.d = 86 ±7.0 mm) were measured during the Two-Day Special

Sport Season and 2,585 lobsters landed by the fishery ranging in size from 65 to 122 mm CL (± 1 s.d = 85 ±7.4 mm) were measured during regular recreational season (Figure 4). FWC's fishery dependent monitoring program measured 957 lobsters at seafood dealers ranging in size from 72 to 113 mm carapace length (CL) (_ ± 1 s.d = 85 ±6.5 mm) that had been landed by the commercial fishery. No difference in lobster size-structure was detected between these commercial landings and those measured during our intercept survey (MS = 83.444; F = 1.646; P = 0.193; ANOVA). A total of 2.1% and 3.3% of the lobsters measured by FWC samplers during the Special Season and regular season intercept surveys, respectively, were below Florida's minimum legal size limit of 76.2 mm CL. A total of 0.5% of the commercially caught lobsters were of sub-legal size.

Table 4.4 (1). Results of multiple regression on effects of the survey type (mail or creel survey), fisher experience, the number of hours fished, and the home residence area of fishers on the group lobster catch rate on (A) Day 1 and (B) Day 2 during the 2002 Special Two-Day Sport Lobster Fishing Season.

A	Unstandardized Coefficients		Standardized Coefficients		
	B	**SE**	**Beta**	**t**	***P***
Constant	**-10.6**	**2.67**		**-3.97**	**> 0.001**
Fishing Party Size	**3.69**	**0.24**	**0.62**	**15.66**	**> 0.001**
Fishing Experience	**5.27**	**1.14**	**0.18**	**4.63**	**> 0.001**
Survey Type	**2.41**	**1.13**	**0.08**	**2.14**	**0.033**

B	Unstandardized Coefficients		Standardized Coefficients		
	B	**SE**	**Beta**	**t**	***P***
Constant	**-10.2**	**2.51**		**-4.07**	**> 0.001**
Fishing Party Size	**3.04**	**0.27**	**0.52**	**11.43**	**> 0.001**
Fishing Experience	**5.09**	**1.23**	**0.18**	**4.13**	**> 0.001**
Hours Fished	**0.83**	**0.30**	**0.13**	**2.81**	**0.005**

Figure 4.4 (1). Boxplots comparing fishing party catch rates (lobsters/day) between mail survey respondents and creel survey participants on Day 1 and Day 2 of the 2002 Special Two-Day Sport Season. Dashed line indicates mean value. Solid line indicates median value.

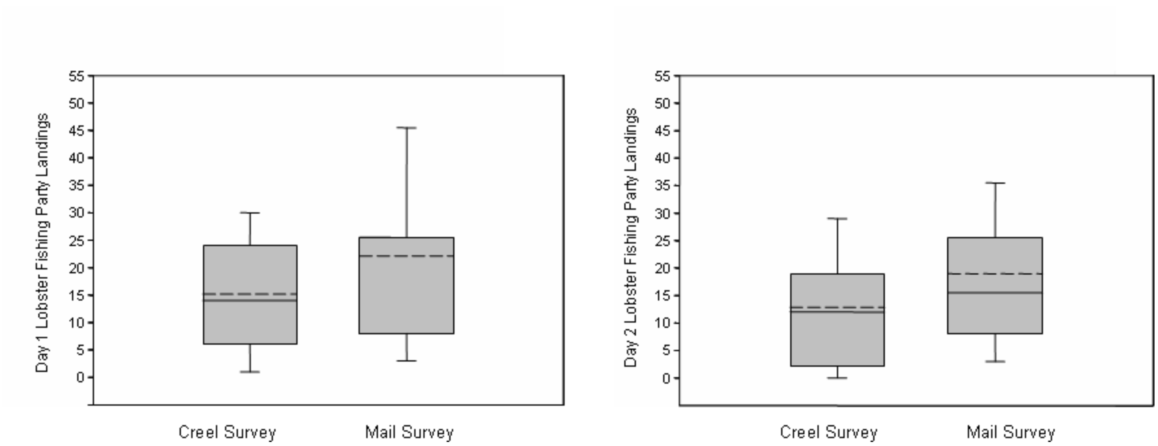


Figure 4.4 (2). Boxplots comparing individual's catch rates (lobsters/day) between mail survey respondents and creel survey participants on Day 1 and Day 2 of the 2002 Special Two-Day Sport Season. Dashed line indicates mean value. Solid line indicates median value.

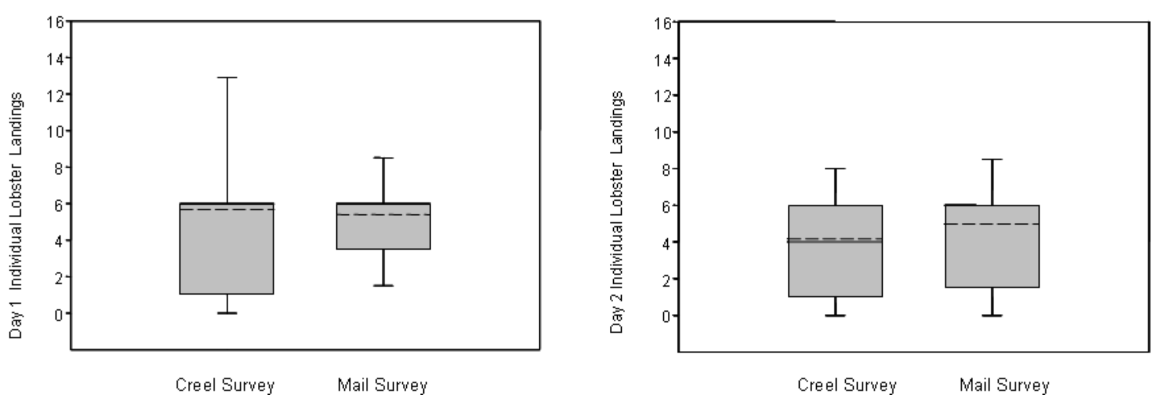


Figure 4.4 (3). Boxplots comparing fishing party and individual catch rates (lobsters/day) between mail survey respondents and creel survey participants from opening day through Labor Day of the 2002 regular lobster fishing season. Dashed line indicates mean value. Solid line indicates median value.

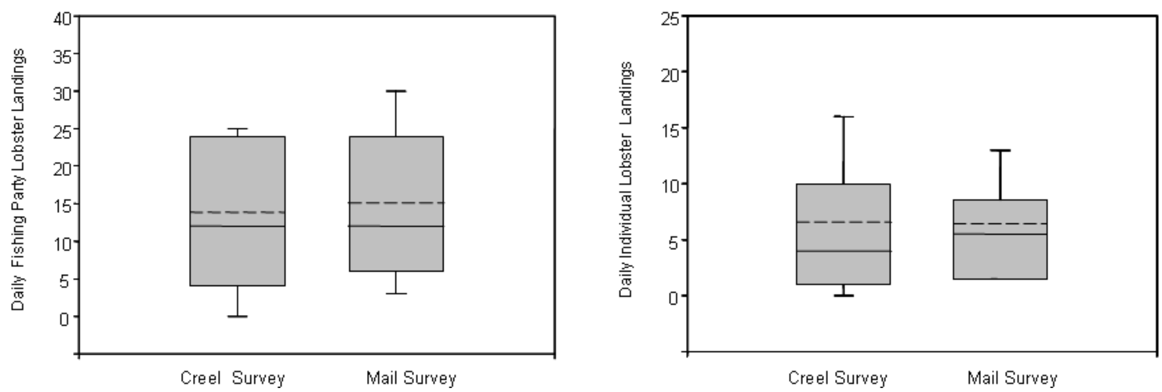
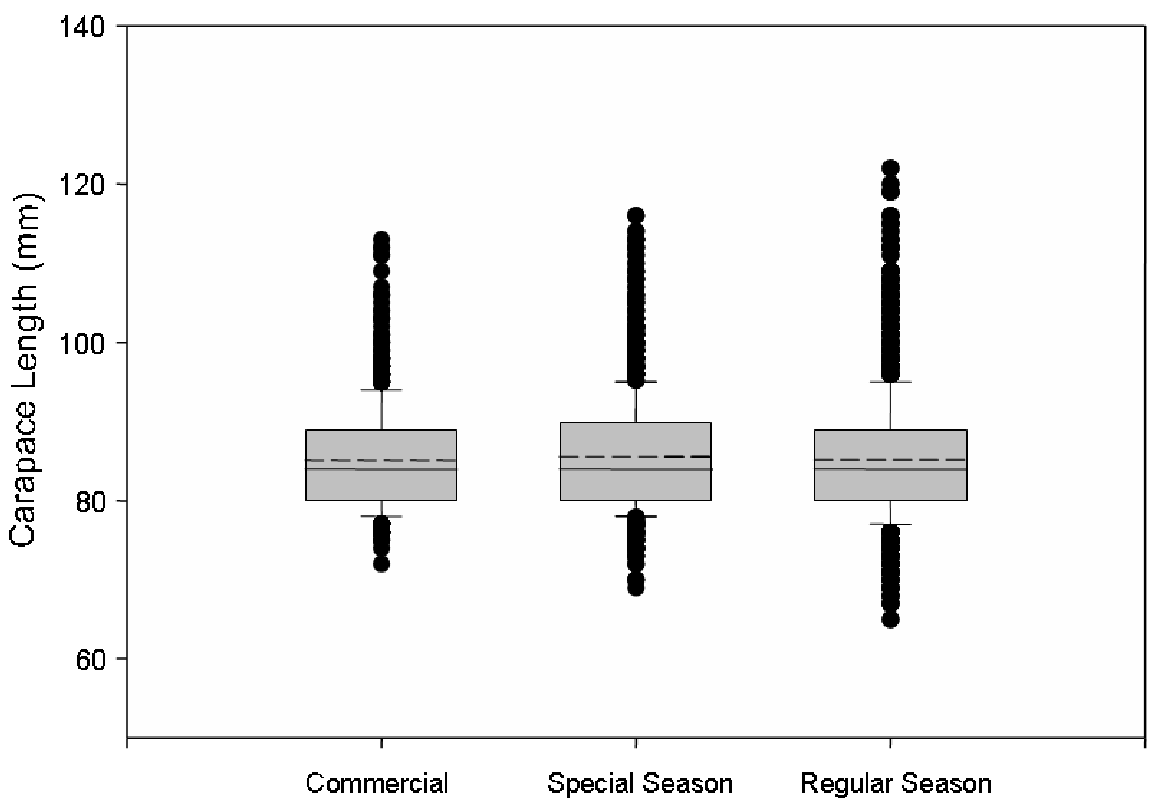


Figure 4.4 (4). Boxplots comparing length frequency of lobsters landed by the commercial fishery during the opening two weeks of the 2002 lobster season in the Florida Keys and those measured during the FWC creel survey during the 2002 Special Two-Day Sport Season and the first two weeks of the lobster fishing season. Dashed line indicates mean value. Solid line indicates median value.



5.0 Fishery-Independent Survey Data

5.1 FWC Puerulus Influx Data

5.1.1 Introduction

Since 1987, The Florida Fish and Wildlife Conservation Commission, Florida Fish and Wildlife Research Institute, has monitored spiny lobster postlarval settlement in the Florida Keys. The information obtained from this effort has established an abundance timeline of spiny lobster postlarval recruitment to the Keys. Their abundance is a potential factor controlling the future harvest of lobsters in Florida. The intent of this program is to establish a stock-recruitment relationship that would allow us to better predict future spiny lobster landings.

5.1.2 Methods, Gears and Coverage

Postlarval collectors are made from hog's hair air conditioner filter material that provides an architecturally complex artificial settlement substrate for postlarvae. Collector frames are constructed of PVC and measure approximately 17" x 18.5". The hog's hair is attached to 6 cross pieces using cable ties, resulting in 12 "leaves" or "pages" (Figure 1). The collectors are buoyed using floats and with rope running through the frame, are clipped to an anchor system consisting of a line buoyed at the surface and attached to cinderblocks on the bottom.

The effective life of the hog's hair is approximately 12 weeks. There is a notable reduction in catch after that, possibly due to fouling. Each collector is numbered individually to monitor its age, and when it has been deployed for 12 weeks, the collector is replaced on the regular sampling date. "Expired" collectors are returned to the laboratory where the frames and/or floats are repaired if necessary, and the hog's hair replaced.

Collectors are retrieved in a fine mesh bag with PVC handles. The bag is important for retaining any postlarvae that may be dislodged when the collector is removed from the water. Each "page" in the collector is examined twice, and the mesh bag and surrounding work area searched to ensure removal of all recruits. Postlarval and juvenile lobster are counted and classified as transparent, semitransparent, pigmented or juvenile.

Our collectors are anchored near shore in shallow water (<2m) near Big Munson Key in the Lower Florida Keys and on the south side of Long Key in the Middle Keys (Figure 2). They are placed parallel to shore near inter-island channels where postlarvae enter the Florida Bay nursery area.

5.1.3 Sampling Intensity – Time Series

Monitoring at Big Munson Key began in March of 1987 and at Long Key in 1993 and continues to the present at both locations. In July of 1991, the sampling interval was changed from weekly to monthly after preliminary studies indicated that 1) weekly sampling schedules were too labor intensive for a long term monitoring effort and 2) monthly sampling during the first quarter lunar phase maximized catch and still demonstrated seasonal trends apparent in previous years.

Five of these modified Witham collectors are recovered and redeployed on the first quarter lunar phase of each lunar month. There are infrequent gaps in the data as a result of inclement weather or other unknown causes of collector loss (a total of 8 months of data are missing), but for a monitoring project spanning in excess of 17 years, this to be expected. Hurricane George, for example, was responsible for the complete destruction of many of the collectors and several months worth of data in 1998.

The lunar timing of our sampling regime is a result of several early studies examining daily, weekly, and monthly settling patterns, postlarvae metamorphosis time, and the length of time recruits stay on the collector following settlement. Results indicated that the bulk of settlement for the lunar month occurred during the first quarter (about day +2). It was also determined that postlarvae metamorphosis from transparent postlarvae to first stage juveniles averaged 8 days, after which time they left the collectors. It was determined that sampling on day +7 would maximize recruitment and minimize losses.

5.1.4 Summary Results – Time Series Analysis

Though spiny lobster postlarvae recruit to the Florida Keys year-round, analyses of the data from both sites indicate a highly correlated seasonal influx. This correlated influx occurs within an annual cyclic pattern with a peak early in the calendar year (February-March) and the lowest settlement occurring during the summer months. Figure 3 illustrates the mean total lobsters per collector per month for data from 1987 through September of 2004. These monthly settlement patterns generally mimic those established by Acosta *et al.* in analyses limited to earlier data.

Current time series analyses were conducted based on an adjusted, October-September annual timeline to avoid partitioning of the early calendar year settlement peak. Data for the months of October-December were rotated into the following calendar year (calendar year +1), whereas the year designation for the months of January-September remained consistent with the respective calendar years in which the data was collected. Gaps in the data primarily occurred in the summer or early fall months when recruitment is lower, and did not appear to impact the adjusted-year time series analyses. Figure 4 illustrates the mean annual (adjusted year) postlarvae and juvenile landings at the two sites over time.

The sharp increase during the first three years of sampling at Big Munson is likely a reflection of differing sampling methods during the early phase of the project, but a source for the similar sharp increase early on at Long Key is yet undetermined. For the past 8 years at Long Key and nearly 15 years at Big Munson, though, settlement patterns have oscillated without trend. As such, there appears to be a disconnect between postlarval settlement and adult lobster landings in the Florida Keys, raising the question of whether post-settlement processes play a larger role in lobster abundance than does recruitment.

5.1.5 Discussion and Decisions

The dataset is appropriate for use as a tuning index. To accommodate the shift in sampling intensity early on, two separate analysis methods have been utilized. The tuning index presented by Bob Muller was developed only from data collected between days +5 and +13 in the lunar cycle, whereas that done by FWRI includes a monthly summation of the data from each of the weekly samples. The decision was made to use the former for the final tuning index for SEDAR purposes.

Figure 5.1 (1). Modified Witham postlarval lobster collector

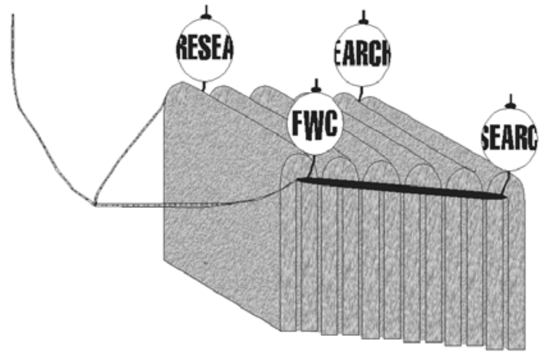


Figure 5.1 (2). Postlarval collector deployment sites

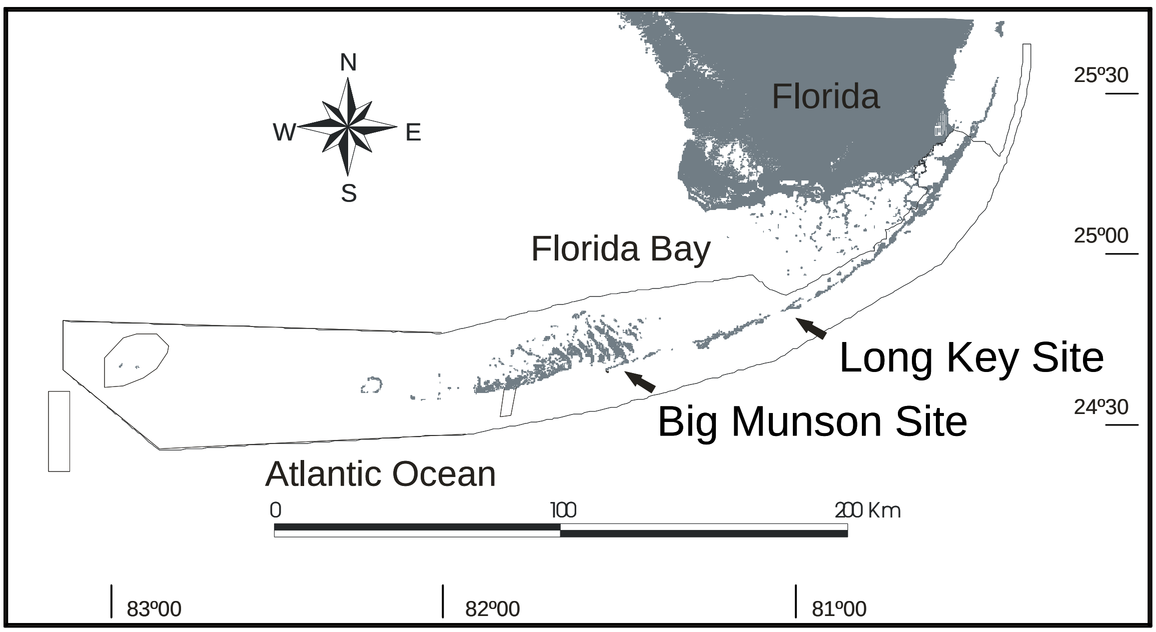


Figure 5.1 (3) . Monthly *Panulirus argus* postlarvae in the Florida Keys. a. Mean number of lobsters per collector at Long Key site, June 1993-September 2004. b. Mean number of lobsters per collector at Big Munson site, March 1987-September 2004. c. Means of all data, both locations

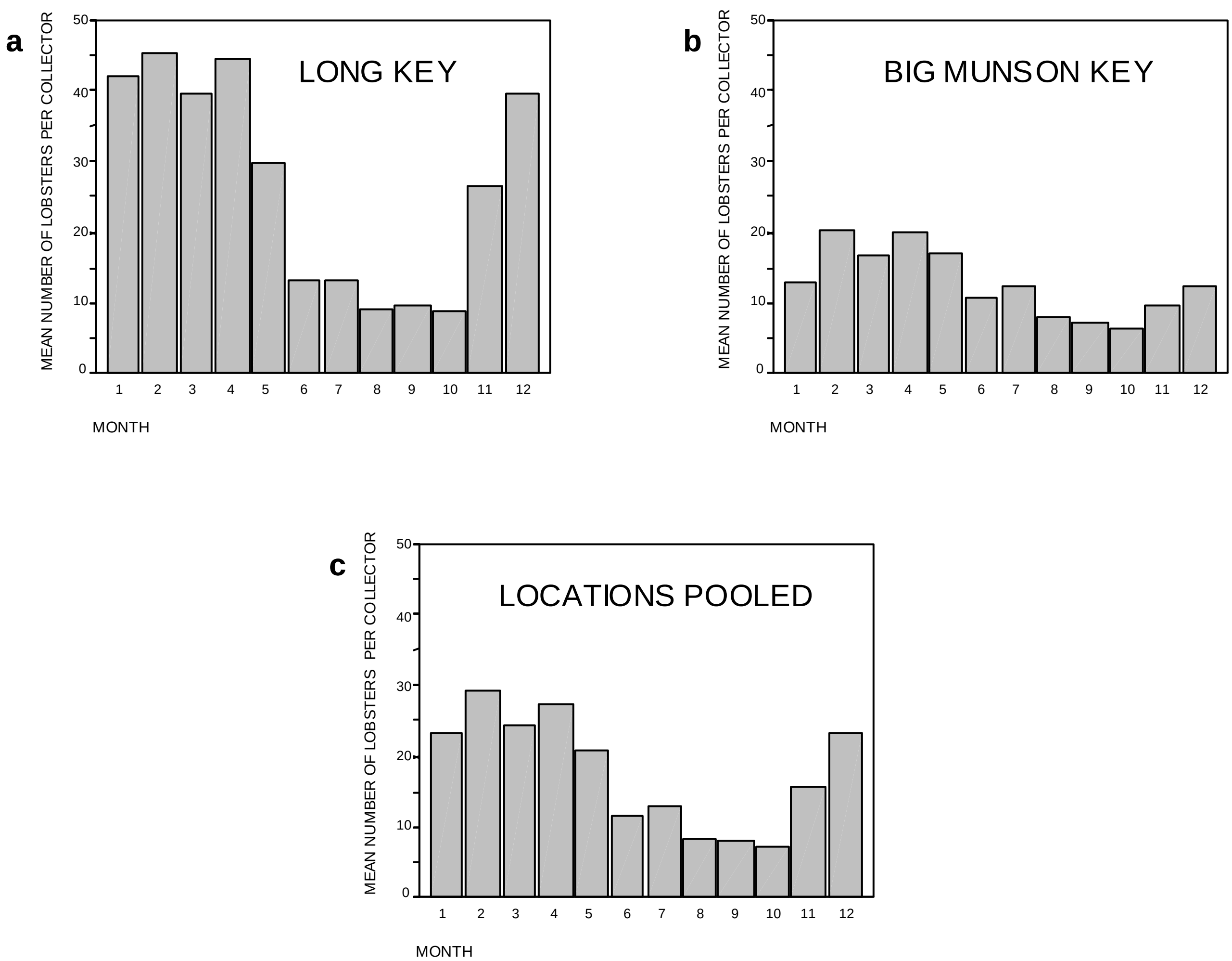


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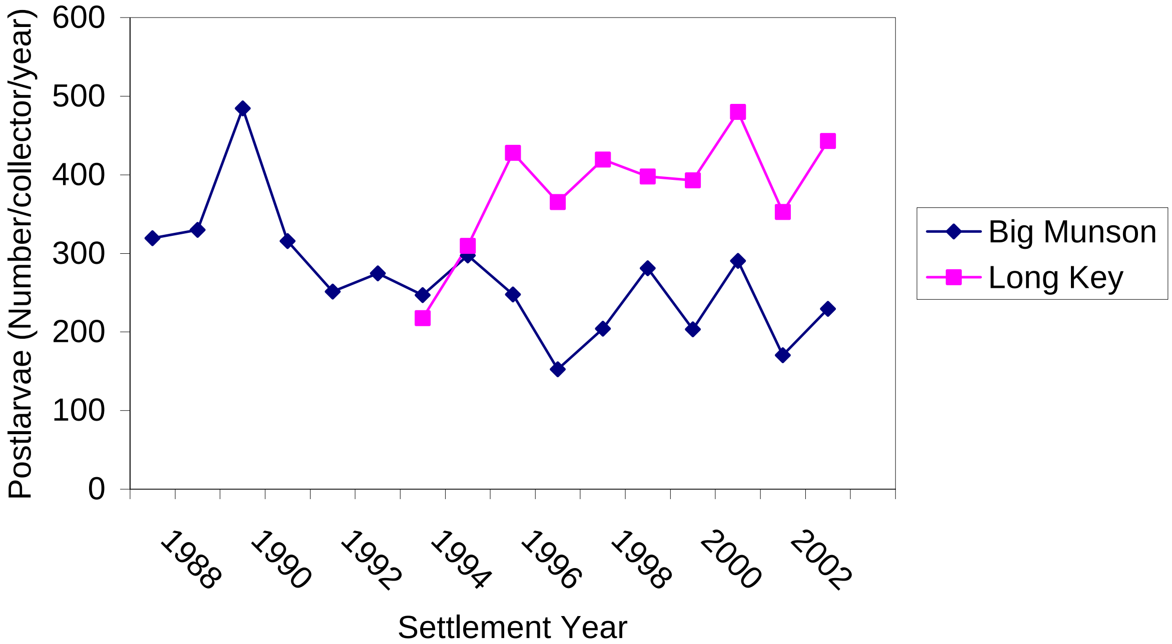
Figure 5.1 (4). Time series of *Panulirus argus* postlarvae settlement in the Florida Keys



5.2 FWC Lobster Monitoring using Timed Surveys

5.2.1 Introduction

We use timed surveys which yield relative abundance estimates (number of lobsters per unit time) rather than transect surveys which yield density estimates (number of lobsters per unit area) to survey lobsters in Florida because lobsters are gregarious and their distribution is patchy. There is a high probability of finding zero lobsters in a randomly placed transect, even when it is placed in high quality lobster habitat were lobsters are abundant. With timed searches, we sample more lobsters on each survey, and obtain more data relating to size, sex ratio, reproductive condition, etc. Additionally, with roving surveys, more time can be spent sampling instead of placing and retrieving transect tapes (Schmitt et al 2002).

FWC lobster monitoring data were obtained in a number of different projects in locations ranging from Biscayne National Park to Dry Tortugas National Park (Table 1). Projects include: 1) MARFIN 518, 2) FKNMS marine reserve monitoring, 3) Biscayne National Park lobster monitoring, and 4) COP lobster monitoring. Each study covered a different time period and sampling periodicity, and focused on different areas and habitats. In each study, however, timed surveys were performed using the same method.

5.2.1 Methods, Gears, and Coverage

Surveys consisted of 60-minute timed searches for spiny lobsters. Capture time was not included as part of the 60-minute search time. Surveys were performed by teams of divers consisting of one "searcher" and one "catcher." Teams searched the dominant lobster habitat at each site. Sites were selected haphazardly from within pre-selected zones, habitats, or areas, depending upon the study. Individual surveys were most often performed by two dive teams that each performed one-half of the 60-minute search. Searches were begun near the boat, with one team searching habitat to starboard or aft of the boat while the other team searched in the opposite direction.

The "searcher" kept time with an underwater stopwatch that was turned off whenever there was a break in the active search. Such breaks included capture time, or when the team had to traverse a large expanse of sand or seagrass to reach approproriate habitat. We counted and attempted to catch all lobsters observed by the "searcher". Lobsters were captured with net and tickle stick, or tail-snares. Lobsters observed by the "catcher" but not the "searcher" were neither counted nor captured. We estimated relative abundance of lobsters as n lobsters observed* hr $^{-1}$.

Captured lobsters were taken to the boat where they were measured. We recorded sex, size, molt stage, and female reproductive activity including the presence of spermatophores and eggs. We also recorded infection of late stage herpes-like lobster virus (HLV-PA) whenever it was observed. Captured lobsters were released after data were recorded.

Surveys were conducted along the Florida Keys reef tract from Biscayne National Park to Dry Tortugas. Location of sample collection for each study is listed in Table 1. In each study, sampling was stratified, at least in part, by habitat. Habitats were : 1) forereef - relatively shallow, usually spur-and-groove, on the seaward side of the reef crest; 2) backreef - shallow rubble and small coral heads on the lee side of the reef crest; 3) offshore patch reef - small patches of hard bottom surrounded by sand or mud, seaward of Hawk Channel, typified by high coral cover and diversity, and abundant octocorals; 4) nearshore patch reef - shallow reefs of star coral landward of Hawk Channel; 5) deep reef - coral and hardbottom seaward of the forereef in 15 to 30 m. In the Dry Tortugas, patch reefs were defined as patches of coral or pinnacles in 3 to 30 m within the reef tract inside Dry Tortugas National Park.

5.2.1 Sampling Intensity – Time Series

We began conducting timed surveys of adult lobsters in 1995 with MARFIN 518. Similar data collection has continued each year to present. Table 1 lists the duration of each study, sampling frequency, and number of replicate samples in each zone or habitat type.

5.2.1 Size data

Roving diver, timed surveys are appropriate for surveying all spiny lobsters large enough to occupy crevice shelters. Lobsters from 10 mm to 184 mm carapace length (CL) are represented in our data. Figure 1 shows mean size of lobsters collected with timed surveys during FKNMS Marine Reserves sampling by fishing season from 1997-2001. Figure 2 depicts mean size of lobsters collected with timed surveys during MARFIN518 sampling by zone from 1996-1999.

5.2.1 Relative Abundance

FWC relative abundance data can be reported in many fashions. For some locations, such as Looe Key and Western Sambo, abundance data were collected at least once each year from 1996 to present. Abundance of all lobsters can be calculated, or data can be parsed by size class (e.g. sublegal and legal-sized lobsters). Data can parsed by habitat (i.e. forereef, backreef, etc.) for each year, or by region (upper, middle, lower Keys, etc.) for the period 1996-2001. Abundance of legal-sized lobsters ranged from 0 lobsters/hr up to 115 lobsters/hr in our surveys, and total abundance ranged up to 188 lobsters/hr. Figure 3 depicts relative abundance of lobsters at 20 sites in Florida Keys National Marine Sanctuary during closed and open fishing seasons from 1997-2001.

5.2.1 Uncertainty and Measures of Precision

In some instances, survey time did not equal 60 minutes. In these instances, relative abundance was extrapolated to N lobsters / hr from N lobsters/minute. These data were collected in a variety of habitats by many different scientific divers. Though conditions varied among, locations, and habitats, and currents and visibility differed from day to day, we assume that these data are standardized in that they are representative of the area that can be searched by one set of eyes. The more complex the habitat, the more three dimensional area to search, the less horizontal area covered in a single survey.

In instances when lobsters were not captured, lobster sizes were estimated to the nearest 5 mm when estimation was possible.

Table 5.2 (1). FWC Projects for which relative abundance (number of lobsters per 60-minute timed-search) of lobsters was determined.

Study	Duration	Frequency	Zones	Habitats	Replicates
MARFIN 518	Spring 1996-Fall 1998, plus additional Dry Tortugas excursion 1999	6-Week Cycles from Feb/March through Sept/Oct for 3 years	Upper Keys: Carysfort reef -Tennessee reef; Middle Keys: Tennessee Reef - Moser Channel (7-mile bridge); Lower Keys: Moser Channel - Western Sambo; West of Key West: Eastern Dry Rocks - Marquesas Rock; Dry Tortugas National Park; Dry Tortugas Fishery; Looe Key National Marine Sanctuary	Forereef, backreef, patch reef (dropped in year 2), deep reef (added in year 2)	Two different, haphazardly selected sites per zone/habitat combination each sampling period
FKNMS Marine Reserves	1997-2001	Two times per year - once in July during the closed fishing season, and once in September/October during the open fishing season	Thirteen marine reserves and paired fishery sites - Carysfort reef to Western Dry Rocks	Forereef, backreef, offshore patch reef nearshore patch reef	Western Sambo/Pelican Shoal : 3 replicate samples per habitat each season; Carysfort/Pacific Reef: three replicates in forereef and backreef each season; Other sites: one replicate per season
Biscayne National Park Lobster Monitoring	2000-2003	2 times per year - once in June during the closed fishing season, and once immediately following the 2-day lobster sport dive season	Biscayne Bay lobster sanctuary and Atlantic waters of Biscayne National Park	Forereef, patch reef, hardbottom	Year 1: 3 forereef, 3 patch reef, and 3 hardbottom sites per season; Years 2&3: 5 foreef, 5 patch reef and 3 hardbottom sites per season
COP Lobster Monitoring	2002-2004	Once per year - during July - closed fishing season	Marine Reserves and paired fishery sites: Western Sambo/Pelican Shoal; Eastern Sambo/Middle Sambo; Looe Key/Maryland Shoal	Forereef, backreef, offshore patch reef	Western Sambo/Pelican Shoal : 3 replicate samples per habitat; Other sites: one replicate

Figure 5.2 (1). Mean size of lobsters during closed and open fishing seasons, 1997-2001. Data collected during FKNMS Marine Reserves sampling. Dashed line represents minimum legal size.

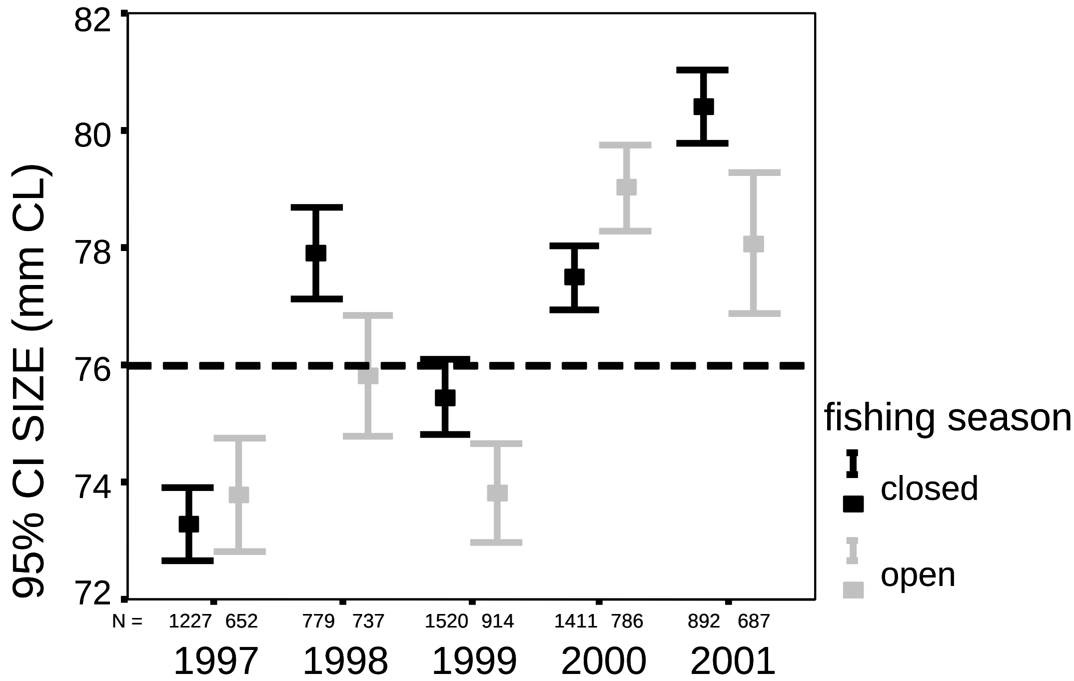


Figure 5.2 (2). Mean size of lobsters by zone, 1996-1999. Data collected for MARFIN518.

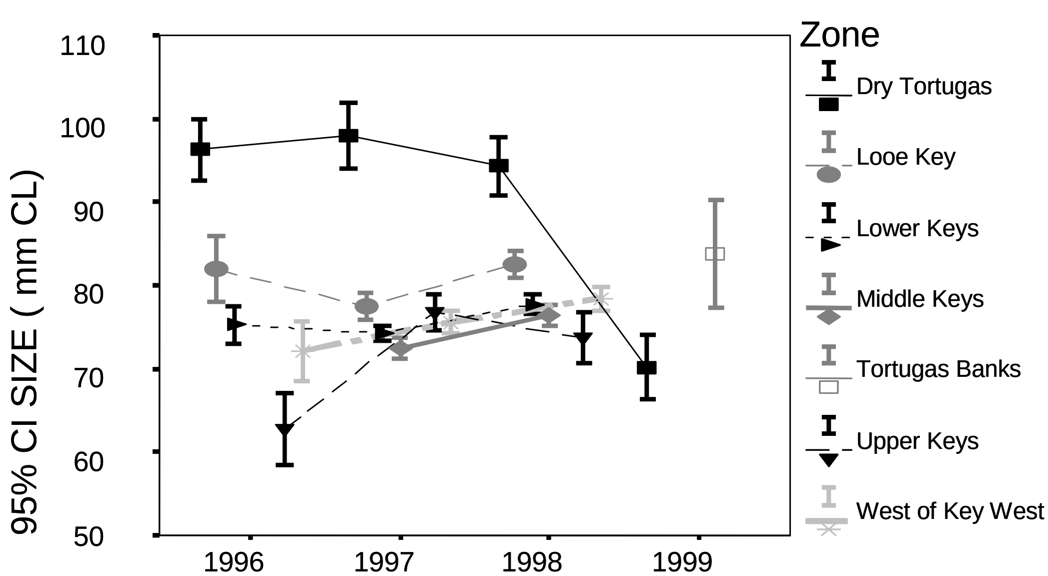
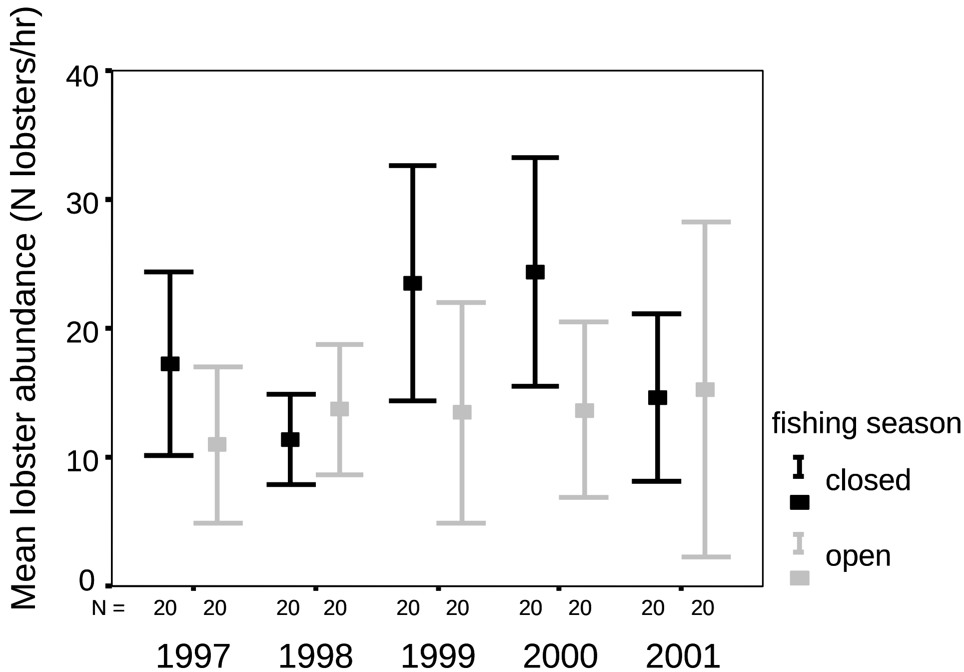


Figure 5.2 (3). Relative abundance of lobsters at 20 sites in the Florida Keys National Marine Sanctuary, 1997-2001 during closed and open fishing seasons. Data were collected for FKNMS Marine Reserve monitoring.



5.3 FWC Adult Monitoring Using Area Based Surveys

5.3.1 Looe Key

Designed purpose and objectives: Evaluate the spiny lobster population in the then newly created Looe Key National Marine Sanctuary. Objectives included surveys of distribution and abundance of spiny lobster, determine male to female ratios, size distribution, reproductive characterizations, and habitat utilization. This project was conducted between 1987 to 1989.

Sampling design: Most of the diver surveys were of one of two types. The first survey type was an abundance survey (table = “lobsters_looekeyabundance”. For this survey type, animals were disturbed as little as possible, presumably to lessen movement tendencies after the survey. Counts were made of the number and gender of lobsters in dens as well as a rough size estimate. Information was also collected regarding to the lobster orientation in the den (i.e.; on the floor or ceiling of den). Data records for this portion of the database are on a per den basis. The presence of other species (especially P. guttatus) was also recorded.

The second survey type was a population dynamics survey (table = “lobsters_looekeypopdyn”). Population dynamics surveys involved handling individual lobsters and collecting detailed information about each lobster. Data records for this portion of the database are on a per lobster basis. Additional observations made for these lobsters included size to the nearest mm, molt stage, and reproductive status.

Methods, gears, and coverage: Surveys were conducted primarily through scuba diver based searches. Portions of the database that used traps contain numbers in the trap field indicating the trap identification number (in table = “lobsters_looekeypopdyn”). Surveys with area searched information are limited to mainly fore reef habitat. Divers measured the area searched by using measuring tapes. In addition, some linear features (i.e.; "blowouts") that sheltered lobsters were also measured.

Survey frequency (intensity): Surveys were conducted bi-weekly during the first year, then quad-weekly to the end of the project.

Size/age data: Lobsters within the "lobster_looekeyabundance" table were binned into size categories (vrs = <45mm; sml = 45-65mm; med = 65-85mm; and lrg = >85mm). Lobsters within the "lobster_looekeypopdyn" table were measured with calipers to the nearest mm.

Other data: The molt stage observations in this study are more detailed than the other FWC adult monitoring studies. In this Looe Key project, molt stage was determined by clipping a pleopod and examining it under a microscope. This yields far more accurate assessment of molt stage than field based observations.

Notes: Some of the strengths of this database include the frequency of surveys and the year round nature of the surveys. The fine level of survey frequency permits, for example, fine-tuning with weather phenomena. It is also uniquely spatially explicit in that each den in the fore reef habitat was measured with respect to it's distance along the axis of the spur and groove, distance to either side of the spur and groove axis, and the distance above the groove (three dimensional coordinates for dens).

5.3.2 Tortugas2000

Designed purpose and objectives: This project was our initial pilot study to explore area-based surveys. The objective was to determine if a detailed habitat assessment could be incorporated with a lobster abundance estimate over a known area. The surveys needed to be concluded within 30 minutes in order to facilitate a large number of scheduled surveys.

Sampling design: Two divers on a survey, each lay out a 25 m tape in opposite directions from a drop site determined by random draw from the habitat map. The area to 5 m on either side of the tape was searched for lobsters. Lobsters were sight-measured (i.e.; were not captured) to the nearest 5mm size bin. Sex and reproductive status was also determined if possible without displacing the lobster. At the conclusion of the search, each diver conducts a habitat assessment on their side of the transect. Habitat assessments include an abiotic footprint component (percent cover of sand, hard bottom, and rubble), a biotic cover component (percent cover of algae, sea grass, sponges, octocorals, coral, and others), the overall slope of the survey area (max and min depth), vertical relief hard and soft structures, and for a rough percent size distribution estimate for both hard and soft biota. Also recorded were the time of the start and end of the dive, the time of the start and end of the transect search, and the maximum depth of the dive

Surveys were conducted with scuba divers carrying measuring tapes, a measuring tickle stick, and dive slate. Surveys were conducted in June 2000. Survey sites are identified in Figure 1.

Figure 5.3.2 (1) Tortugas 2000 locations of surveys:

5.3.3 Spree 2002

Designed purpose and objectives: This project was a multi-species (fish and lobster) population assessment and habitat assessment of the reef tract from Key Biscayne to Dry Tortugas.

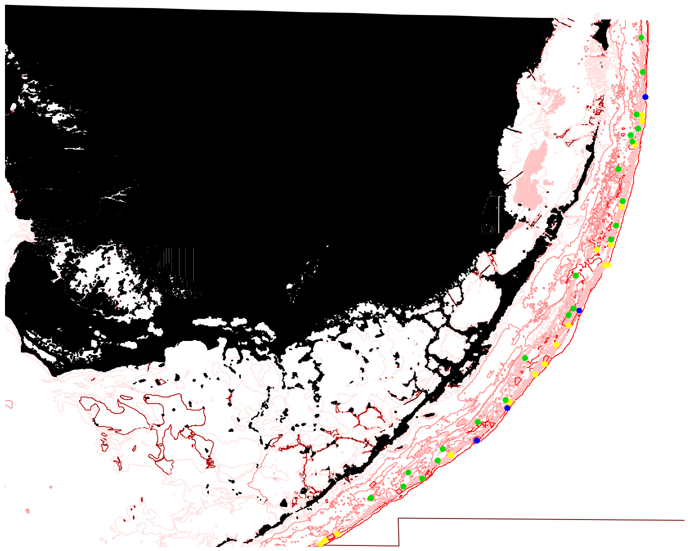
Sampling design: A habitat map with 200m^2 squares was utilized to create random stratified sites for lobster surveys (see Spree2004 section for a sample view of a small part of the habitat map). Strata were based on habitat type and depth. On this cruise we had two teams of two divers. Two divers were used per survey. Each diver lay out a 25 m tape in opposite directions from a drop site determined by random draw from the habitat map. The area to 5 m on either side of the tape was searched for lobsters. Lobsters were sight-measured (i.e.; were not captured) to the nearest 5mm size bin. Sex and reproductive status was also determined if possible without displacing the lobster. At the conclusion of the search, each diver conducts a habitat assessment on their side of the transect. Habitat assessments include an abiotic footprint component (percent cover of sand, hard bottom, and rubble), a biotic cover component (percent cover of algae, sea grass, sponges, octocorals, coral, and others), the overall slope of the survey area (max and min depth), vertical relief hard and soft structures, and for a rough percent size distribution estimate for both hard and soft biota. Also noted for each transect was the presence or absence of P. guttatus, S. gigas, Diadema, and fishing debris (traps, rope, and concrete). Also recorded were the time of the start and end of the dive, the time of the start and end of the transect search, and the maximum depth of the dive

Methods, gears, and coverage: Surveys were conducted with scuba divers carrying measuring tapes, a measuring tickle stick, and dive slate.

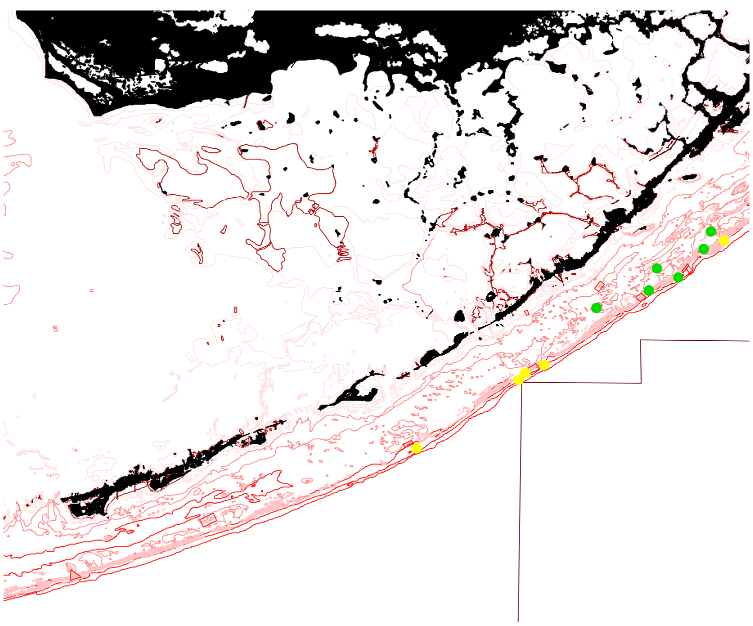
Survey frequency (intensity): Once time set of surveys from May through June in 2002. There were three 10 day legs on this cruise.

Other data: see sampling design. We have the lobster population and habitat assessments portion of the data.

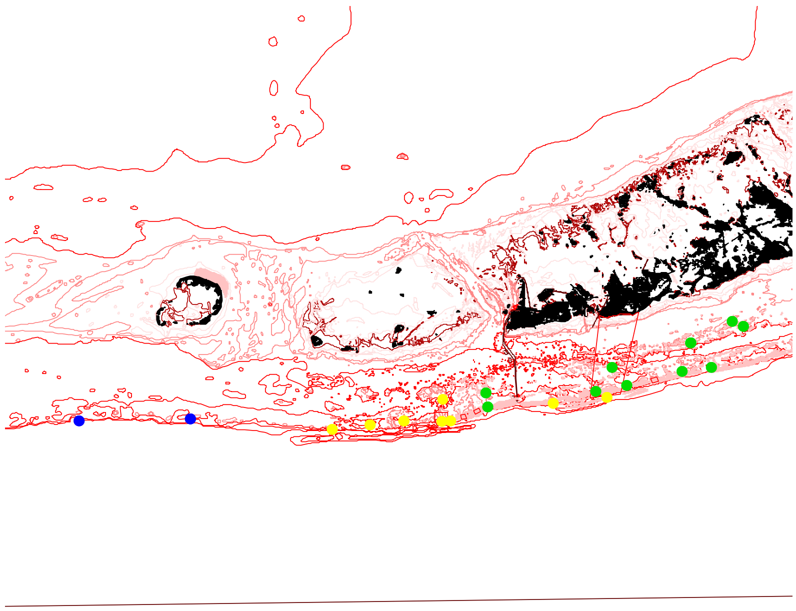
Figure 5.3.3 (2). Spree 2002 survey sites
Leg 1.



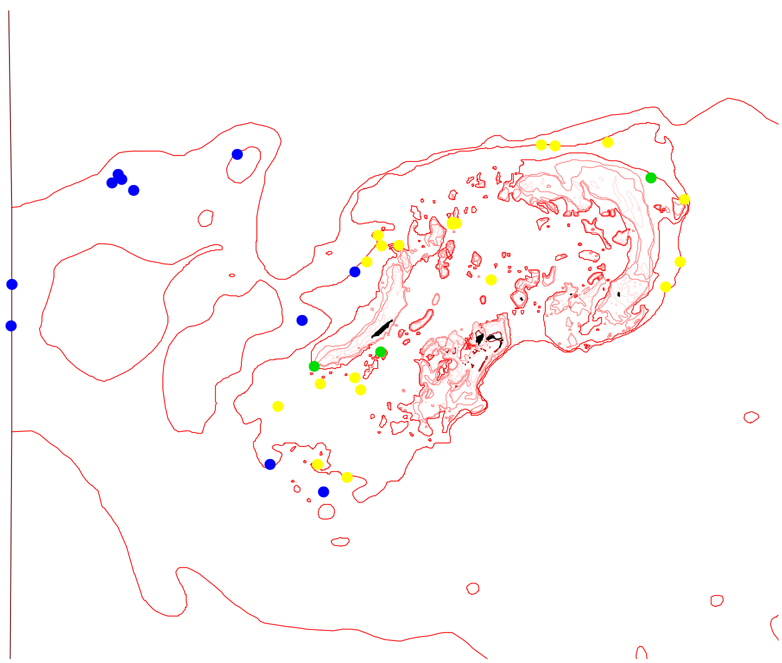
Leg 2a.



Leg 2b.



Leg 3.



5.3.4 Spree 2004

Designed purpose and objectives: This project was a multi-species (fish and lobster) population assessment and habitat assessment of the Dry Tortugas and Tortugas Bank.

Sampling design: A habitat map with 200m^2 squares was utilized to create random stratified sites for lobster surveys (Figue 1. Strata were based on habitat type and depth. On this cruise we had two teams of two divers on the first leg and three teams of two divers on the second leg. Two divers were used per survey and each two diver team scheduled two surveys per dive. Divers laid out a 36 m tape from a drop site determined by random draw from the habitat map. Divers then searched 7 m on one side of the tape for lobsters. Lobsters were sight-measured (i.e.; were not captured) to the nearest 5mm size bin. Sex and reproductive status was also determined if possible without displacing the lobster. At the conclusion of the search, each diver conducts a habitat assessment on their side of the transect. Habitat assessments include an abiotic footprint component (percent cover of sand, hard bottom, and rubble), a biotic cover component (percent cover of algae, sea grass, sponges, octocorals, coral, and others), the overall slope of the survey area (max and min depth), vertical relief hard and soft structures, and for a rough percent size distribution estimate for both hard and soft biota. Also noted for each transect was the presence or absence of P. guttatus, S. gigas, Diadema, and fishing debris (traps, rope, and concrete). Also recorded were the time of the start and end of the dive, the time of the start and end of the transect search, and the maximum depth of the dive

Methods, gears, and coverage: Surveys were conducted with scuba divers carrying measuring tapes, a measuring tickle stick, and dive slate.

Survey frequency (intensity): Once time set of surveys from June to July in 2004. There were two 10 day legs on this cruise. Other data: see sampling design. Survey sites are depicted in Figure 2.

Figure 5.3.4 (1) Dry Tortugas and Tortugas Bank section of the habitat map:

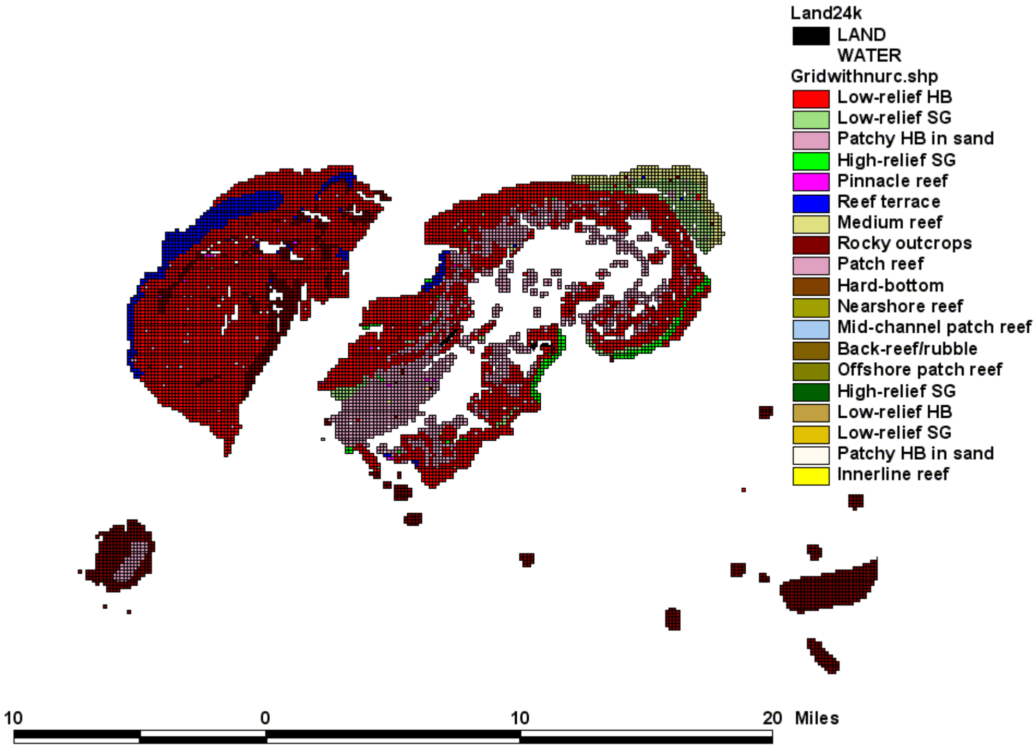
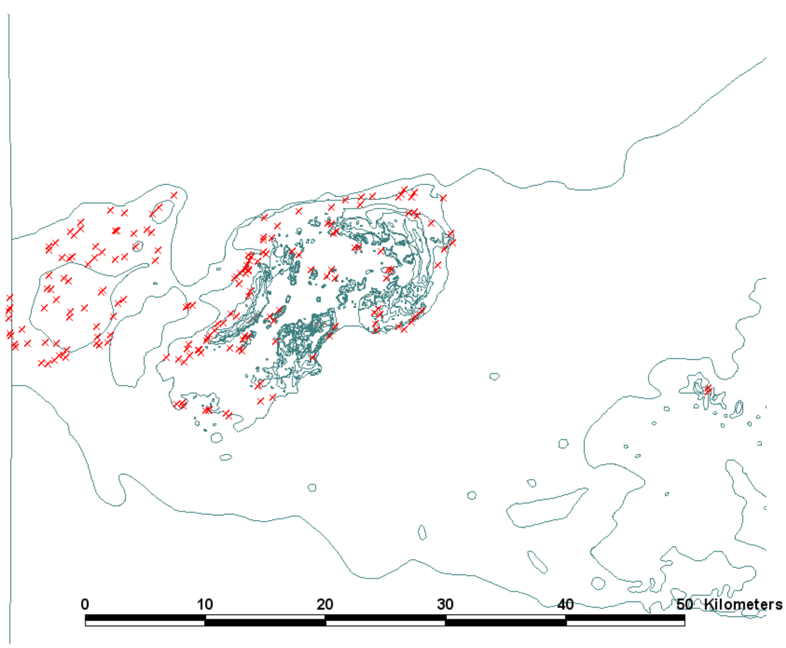


Figure 5.3.4 (2) Location of surveys in Spree 2004



5.3.5 Reserves 2004

Designed purpose and objectives: This project is a pilot study to test area based surveys in the Keys. A series of computer simulations that attempted to convert years time-based surveys into an approximation of area-based surveys suggested certain number of area-based 500 m^2 surveys should detect a statistically significant difference in density of lobsters between the Western Sambo Ecological Reserve and the surrounding area. A series of timed-based surveys were also conducted at this time.

Sampling design: Two divers on a survey, each lay out a 25 m tape in opposite directions from a drop site determined by random draw from the habitat map. The area to 5 m on either side of the tape was searched for lobsters. Lobsters were sight-measured (i.e.; were not captured) to the nearest 5mm size bin. Sex and reproductive status was also determined if possible without displacing the lobster.

Methods, gears, and coverage: Surveys were conducted with scuba divers carrying measuring tapes, a measuring tickle stick, and dive slate.

Survey frequency (intensity): Once time set of surveys in June 2004.

Other data: Eighty surveys were completed, 40 inside Western Sambo and 40 in and around Pelican Shoal (Figure 1).

Figure 5.3.5 (1) Reserves 2004 locations of surveys :

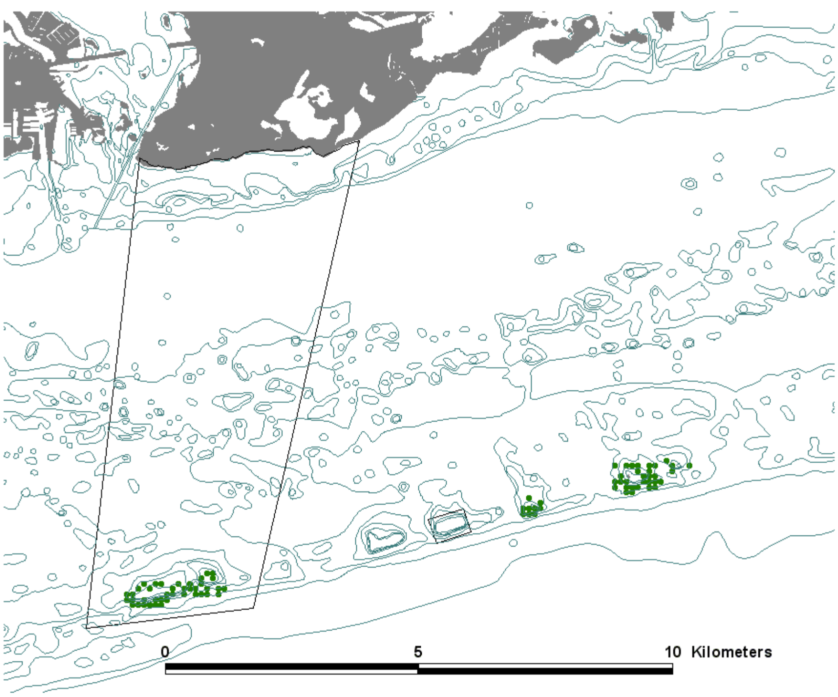


Table 5.3 (1). Area based FWC adult lobster surveys using scuba diver observers.

Project	Time frame	Region	Records, surveys, or transects	Notes
Looe Key	1987-1989	Looe Key	>23K records 1,431 surveys	Bi-weekly 1st yr/year round then Quad-weekly; areas measured
Tortugas2000	June 2000	Tortugas	40 surveys	survey= 500m^2 transects with habitat characterizations
Spree2002	M-Jn 2002	Tortugas	188 surveys	survey=2*500m^2 transects with habitat characterizations
Spree2004	Jn-Jl 2004	Tortugas	703 transects	transect= 500m^2 with habitat characterizations
Reserves2004	July 2004	WSER Pelican	80 transects	transect= 500m^2

5.4 ODU Juvenile Timed Surveys

5.4.1 Description of Survey:

There is no formal, long-term monitoring program for juvenile *P.argus* in south Florida. However, over the years there have been various experimental studies and, in some cases, widespread surveys that have used similar methods and thus yielded standardized information on juvenile lobster populations at shallow (< 3m) hard-bottom sites in the Florida Keys and Biscayne Bay (Table 1). In the case of experimental studies, the spatial coverage of the datasets tends to be limited. These data were collected by personnel from Mark Butler's lab at Old Dominion University, sometimes in collaboration with personnel from Bill Herrnkind's lab at Florida State University or with personnel from the FWC Marathon Field Lab. Because the data collection procedures were consistent among these studies, these data may permit more reliable comparisons among years and sites. A brief summary of each study follows:

Project Code: ODB
This was an experimental study designed to test habitat limitation of recruitment of juvenile spiny lobster. Habitat structure on each of the nine experimental sites was measured once at the start of the study. Diver census of lobster population structure was conducted approximately monthly for a year. Six of the nine sites had artificial structures added to them; in addition, newly settled first and second stage juvenile lobsters were added to three of the block sites. Field sites are restricted to one area in the middle Keys near Old Dan Bank.

Project Code: EARTH
This manipulative field study was conducted at sites in the middle Keys and was designed to investigate the relationship between postlarval supply, local habitat structure, and local patterns of postlarval settlement. All of the sites surveyed were natural sites.

Project Code: JEP
This was an experimental study with sites near the Lower Arsnicker Keys in Florida Bay. At those sites the goal was to evaluate recruitment limitation in juvenile lobster, however, the methods employed for determining juvenile abundance in that study (density estimates) are not consistent with those of other studies noted here where CPUE was used. The methods used to determine algal coverage were identical to other studies except that the locations of transects on each site were fixed not hapzardly selected each time period

Project Code: FIELD
These data are part of collaborative project (with Jennifer Field, M.S. student at Old Dominion University) involving both a field and laboratory investigation of postlarval lobster transport and their susceptibility to various temperatures and salinities that might be encountered in Florida Bay. Field sites are largely restricted to the middle and upper Keys and into Florida Bay.

Project code: PBLOOM
This project was a resurvey, conducted after the 1990-1991 cyanobacteria blooms and associated sponge die-offs that occurred in the middle Keys, of previously surveyed sites so as to assess the impact of these events on hard-bottom habitat structure and juvenile lobster populations. Sites in the upper, middle, and lower Keys were included for comparative purposes

Project Code: RAMS
This collaborative field project (with Richard Ramsdell, M.S. student at Old Dominion University) was conducted at sites in the middle and lower Keys. It was an experimental mark-recapture based study designed to investigate the relationship between various juvenile lobster population dynamics (e.g., size-specific growth, movement, survival, etc.) and habitat structure.

Project Code: MAVRO
This project was designed as a field survey of hard-bottom habitat structure and juvenile lobster population structure in the upper, middle, and lower Florida Keys. It was the first comprehensive study of these features and predated GIS-based depictions or any benthic mapping of the shallow waters of the Florida Keys. Site locations were chosen to provide a more or less uniform coverage of the region.

Project Code: ACID
This mark-recapture based field project was conducted in the middle Keys inside and outside of areas recently impacted by the massive sponge die-off which occurred in the region in 1990-1991. The goal of the study was to experimentally test the efficacy of deploying

artificial habitat structures (designed to mimic the small, scattered shelters used by juvenile lobsters) as a means to boost local recruitment of lobsters. A key feature of the study was the quantification of lobster population dynamics (i.e., growth, nutritional condition, survival, movement) relative to habitat manipulation at different spatial scales. Therefore, the sites in this study represent a mix of natural sites unimpacted by sponge die-off, natural sites that were impacted by the sponge die-off, and impacted sites on which artificial structures were deployed in different spatial configurations.

Project Code: SCHR
This collaborative mark-recapture based field project (with Jason Schratwieser, M.S. student at Old Dominion University) was conducted at sites in the middle Keys and was designed to test the effect of resident vs. transient predation regimes on juvenile spiny lobster population dynamics. Therefore, roughly half of the sites were purposely chosen to contain large solution holes with resident red groupers

Project Code: SGHB
This manipulative field study was conducted in the middle Keys and was designed to determine whether postlarval lobster settlement and the survival or growth of juvenile lobsters differed significantly in seagrass vs. hard-bottom habitats.

Project Code: RCRT
This manipulative field study was conducted at sites in the upper, middle, and lower Keys and was designed to investigate a variety of relationships between postlarval supply, habitat structure, and juvenile lobster recruitment on a large-scale. Half of the sites were unmanipulated natural sites and the other half were augmented with artificial structures for use by juvenile lobsters. In addition, the study also included data on postlarval supply to several locations in the upper, middle, and lower Florida Keys over four years were collected in conjunction with the benthic site work described above. The postlarval collector data are presented under a separate project description: RCRT – Recruitment Study Collector Data.

Project Code: BEHR
This collaborative (with Donald Behringer, Ph.D. student at Old Dominion University) field and laboratory based study was designed to test the impact of natural and artificially-enhanced shelter density on juvenile lobster population dynamics (survival, growth, nutritional condition, residency patterns) and disease transmission (PaV1 disease). The study was conducted in the middle and lower Keys and involved both natural sites and those to which artificial structures were added

Project Code: CARA1 and CARA2-3
This multi-year monitoring study was conducted in the upper, middle, and lower Keys at unmanipulated, natural sites whose location was chosen using a double-stratified random sampling design. The locations of transects for determination of habitat structure and macroalgal cover within sites were haphazardly chosen in year one, and then permanently located (described below) thereafter.

Project Code: BISC

This field study in Biscayne Bay was initially designed as a standard rapid-assessment survey of hard-bottom habitat structure and juvenile lobster population structure, but later involved a comparison of habitat recovery following Hurricane Andrew. All sites are natural sites. The first survey was immediately before the hurricane, the second survey just after the hurricane, and subsequent surveys document recovery over time.

5.4.2 Methods, Gear, & Coverage

We have recently aggregated all of the known juvenile lobster datasets that used the same collection methods into a single, relational meta-database (formatted for Microsoft Access). In addition to the standardized surveys of lobster on hard-bottom in natural shelters detailed below, this same group of researchers has also conducted other less extensive surveys where study site area was delineated (25 m x 25 m or 50m x 50m survey sites), thus permitting estimates of juvenile *P. argus* density. In other studies, standardized artificial shelters were placed on sites and information on the *P. argus* using them was recorded. Mark-recapture studies of varying duration have also been conducted on a subset of sites over a limited geographic region, primarily in the middle Keys.

In addition to data on juvenile lobster population structure, data on hard-bottom habitat structure were also collected at each site. The standardized procedures used to collect information on juvenile lobster and hard-bottom nursery habitat structure are briefly described below. The frequency of sampling for each study varied, as did the spatial coverage of each study and these are noted in Table 1.

5.4.3 Lobster Population Structure

The abundance and individual characteristics (as defined below) of *P. argus* present on each hard-bottom site was determined by divers who collected lobsters that they encountered as they searched prominent crevice-bearing structures on non-overlapping portions of the site. These dives were timed and all of 1 hr duration (30 mins per diver), yielding catch-per-unit-effort (CPUE) estimates of relative lobster abundance for each site. Juvenile lobsters dwelling in typical hard-bottom nursery habitat are rarely found in large groups (Childress and Herrnkind 1997; Behringer 2003) and once located, they are easily and quickly captured (usually just a few seconds). Therefore, the survey period for these studies reflects the total time underwater (i.e., search + capture time), not just search time. This is in contrast to the situation with adult lobsters, whose capture takes longer and therefore the survey times only include search time (see section on FWC Adult Monitoring using Timed Surveys).

Once lobsters were located, divers used “tickle sticks” and hand-nets to capture the lobsters, which were then placed in mesh holding bags (attached to the divers belt) until brought to the vessel for data processing. In some studies, large juvenile lobsters (> 50 mm CL) were not collected and their size was simply recorded as “> 50 mm CL”. Occasionally lobsters evaded capture (est. < 5% of sightings), but in those cases their estimated size was noted and they were included in the data set. Individual characteristics of all lobsters collected were determined on-board a vessel and all lobsters were then returned to the site alive. Certain individual characteristics that we measured were common to all studies (e.g., sex, carapace length, estimated molt condition [i.e., pre-molt, post-molt, intermolt]), whereas others were recorded in a subset of the studies (e.g., shelter type captured from, number of cohabitants in shelter, molt stage, type and number of injuries, wet weight, blood protein concentration, PaV1 infection).

5.4.4 Habitat Structure

After the early benthic stage, juvenile P. argus use crevice shelters of various types for daytime refuge. Thus, the abundance of various prominent hard-bottom structures on each lobster survey site was also determined by divers who established on each site 2m x 25m belt transects (typically four of them; sometimes fewer and sometimes < 25m long if logistical problems arose). Transects were non-overlapping and haphazardly situated on each site, with the exception of the CARA study. In that study, the locations of the four transects were permanently marked and radiated out from the center of the site in the four cardinal directions (N, S, E, W). The taxonomic specificity of this characterization varied among studies: coarser classifications were used in earlier studies whereas more recent studies were more species-specific.

5.4.5 Bottom Coverage of Macroalgae

The preferred settlement habitat for *P. argus* is the red algae *Laurencia spp*., which occurs primarily on hard-bottom sites. Therefore, the percent cover of *Laurencia spp.* was typically estimate on each lobster survery site using a line transect method. At the same locations where the belt transects were established (see above), divers determined the positions along a 25m long line where *Laurencia spp*. occurred, by noting the beginning and end points of each patch of macroalgae. Depending on the study, the percent cover of other types of vegetation may also have been noted (e.g., the seagrasses *Thallassia testudinum* and *Syringodium filiforme*, calcarious green algaes such as *Halimeda* sp. and *Pennicillus* sp., and various complexes of the above).

Table 5.4 (1): Summary information for the juvenile *P. argus* survey data included in the ODU/FSU/FWC metadatabase.

Project Code	Years	# Natural Sites / # Sites with Art. Shelter	Sample Frequency	Geographic Coverage*	Investigators
ODB	1988-89	3 / 6	~ 1/mo.	M	ODU/FSU
EARTH	1988-89	22 /0	1/yr	M	ODU/FSU
JEP**	1990-93	9/ 18	~ 1/mo.	M	ODU/FSU/FWC
FIELD	1992	20 / 0	once	U & M	ODU
PBLOOM	1993	22/ 0	once	U, M & L	ODU/FSU/FWC
RAMS	1993-96	18 / 0	once	U & M	ODU
MAVRO	1994	75/ 0	once	U, M & L	ODU/FSU/FWC
ACID	1995-97	6 / 6	~ 4 mos.	M	ODU/FSU/FWC
SCHR	1995-97	16	once	M	ODU
SGHB	1997	6	~ 6 mos.	M	ODU/FSU/FWC
RCRT	1998-02	12 / 12	~ 4 mos.	U, M & L	ODU/FSU
BEHR	1998-02	4 / 8	~ 6 mos.	M & L	ODU
CARA1	2002	107 / 0	once	U, M & L	ODU
CARA2-3	2003-04	32 / 0	1/yr	U, M & L	ODU/FWC
BISC	1992, 1993 & 2002	9	1/yr	B	ODU/FSU/FWC

* Geographic coverage code:

U = Upper Keys, M = Middle Keys, L = Lower Keys, B = Biscayne Bay

** JEP juvenile *P. argus* data are density-based not CPUE but may need for temporal continuity; if so, need CPUE conversion estimation.

5.5 FWC Juvenile Surveys

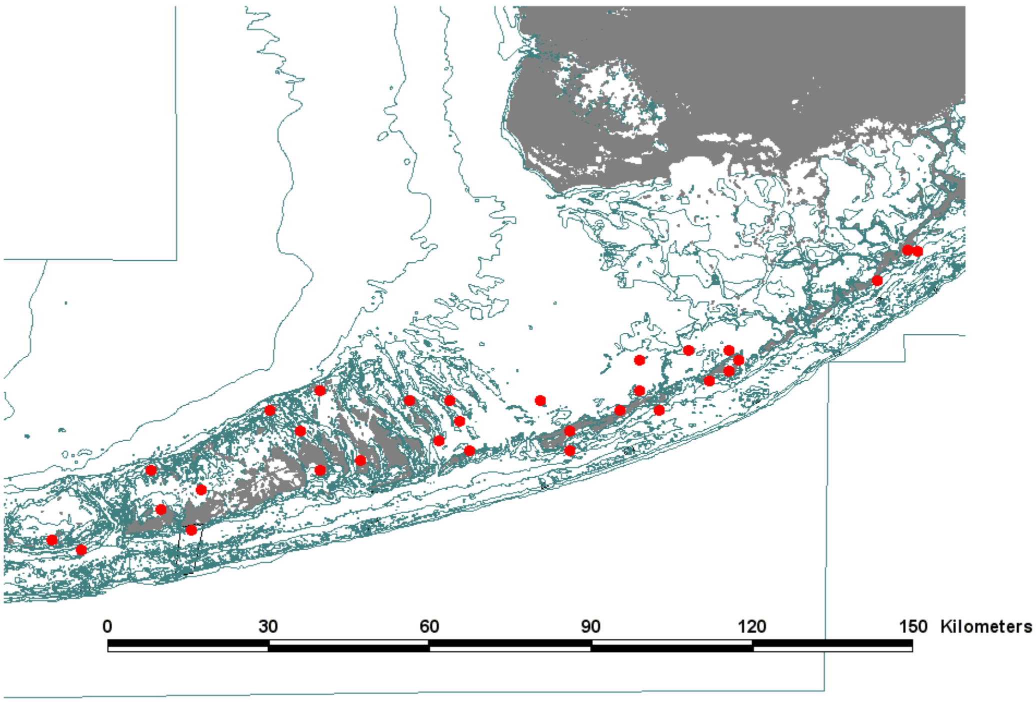
5.5.1 Nearshore Hardbottom Surveys of Juvenile Lobsters

Design purpose and objectives: This is a near-shore hard-bottom assessment project that traces its roots back to a project two years of data collection known under the acronym CARA. The purpose is to characterize fish and lobster distribution and abundance with habitat assessments. CHMP was conducted during 2003 and 2004. Permanent sites are depicted in Figure1.

Sampling protocols and details: Thirty-two permanent monitoring sites throughout the near-shore regions of the Florida Keys were selected through pilot surveys and habitat maps. A permanent marker on the bottom marks the center of each site and additional markers on each of the four cardinal directions of the compass was placed 28 meters from the center marker (25 meter transects with the first three meters of tape next to the center marker not included in the transect). Transect areas were 25 by 2 meters for all sub-surveys except patch forming algae. Patch forming algae transects were a linear 25 meters. "Full" surveys were conducted quarterly, however, other types surveys were conducted on these same sites at different times. A full survey may only be conducted if visibility exceeds 1.5 meters. A full survey consists of the following observations; (1) physical data – (a) water depth, salinity, and temperature; current directions and strength category (i.e. "strong"); time of day; wind direction and speed; percent cloud cover; and horizontal bottom secchi depth; (2) four fish transects with species, size structure, and abundance counts; (3) four transects motile invertebrate species abundance counts (including lobster); (4) four transects of patch forming marine plants (to species or genera in most cases) with size and height on patch in cm; (5) four transects of presence absence of non-patch forming marine plants (i.e. sargassum). Also part of the full survey were four roving searches, two by fish divers and two by invertebrate divers. All four divers search different quadrants of the site. The two roving fish surveys were 10 minutes search time each and consisted of size and count for different species. The two roving invertebrate surveys were 10 minutes search time as well. Roving invertebrate surveys include counts of lobsters and presence/absence of large (>5cm) invertebrates (i.e. octopus, horse conch, Cassiopeia). Lobsters were captured whenever possible to bring them to the boat for more detailed observations. In order to standardize search times across different densities of lobsters, capturing and handling time was not included as search time. Once brought to the boat, lobsters were examined to determine size, sex, molt stage, injuries such as missing legs, and a check for the presence of the lobster virus was also conducted. (Note: Algal transect patch forming and non-patching forming surveys were not conducted at the start of CHMP. Also, the inclusion of large invertebrates in the roving invertebrate search was not conducted at the beginning of CHMP)

Other types of surveys were conducted at the beginning and ending of CHMP. These surveys focused on non-motile invertebrates. Four 25 by 2 meter transects as above were conducted for larger non-motile invertebrates (primarily sponges, octocorals, corals, and anemones). For selected species of sponges (i.e. Loggerhead sponge), up to 6 measurements of the diameter and height of sponges were taken on each transect. For selected species of octocorals, up to 6 measurements of height were taken on each transect. Marine plant transects were also conducted as described above. For small non-motile invertebrates (i.e.; volcano sponges, lesser starlet corals), four one meter square quadrates were placed a specific meters marks along each transect and one meter away from the center line of the transect.

Figure 5.5.1 (1).Location of CHMP permanent sites:



5.6 Sentinel Fisher Survey

5.6.1 Introduction

The FKNMS funded a study from 1998 through 2001 to use commercial fishing trap gear and fishermen to monitor spiny lobster abundance and size in and adjacent to the Western Sambos Ecological Reserve. The Projects title was *Four-Year Spiny Lobster Fishery Monitoring of the Western Sambos Ecological Reserve and Adjacent Areas (FKNMS Sentinel Fisheries Project)* and the principal investigator was Douglas Gregory, UF/IFAS Monroe County Extension, 1100 Simonton Street, Key West, FL 33040, Drg@ufl.edu. During the first two years of the study legal-size lobsters were also tagged. Subsequent recapture rates were so low (5%) that tagging was discontinued.

The specific objectives of the study were to: 1. Directly involve commercial fishermen in monitoring; 2. Determine how abundance and size differ among reserve and adjacent non-reserve areas.; and 3. Determine if the reserve is contributing yield to adjacent areas.

5.6.2 Methods

The reserve was established in July 1997. Sampling started one year later in June 1998 and continued through December 2001.

Nine fixed sample sites were chosen in and adjacent to the reserve between the shoreline from Boca Chica Key to Saddlebunch Keys and the outer reef from Western Sambos to Pelican Shoal. The nine sites were distributed among three different habitat zones in three different areas perpendicular to the shore and reef (see Figure 1). The three habitat zones were the shallows patch reefs, mid-channel patch reefs and offshore patch reefs. The three areas included the Western Sambos Ecological Reserve, and similar habitats parallel to the reserve and in increasing distance from the reserve inshore of the Middle Sambos, and Pelican Shoal reefs.

Standard commercial wooden slat traps were used and fished with cowhide as the only bait. Traps were initially set on the week of the full moon and, weather permitting, were sampled in each of the three subsequent weeks.

Figure 5.6 (1). Location of Sentinel Fisheries sample sites. Each black line represents a ten-trap string equal to about one mile in length.

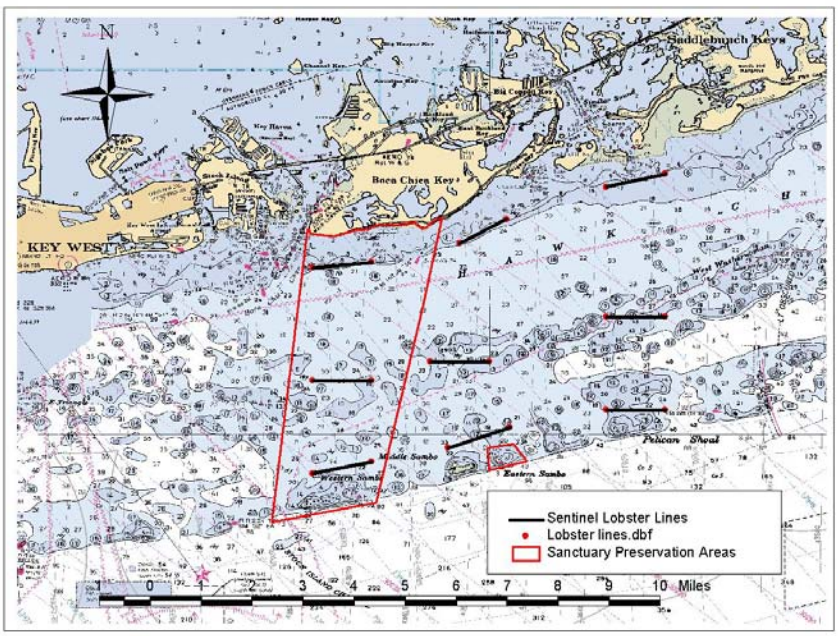


Figure 5.6 (2) Size differences between reserve and non-reserve lobsters

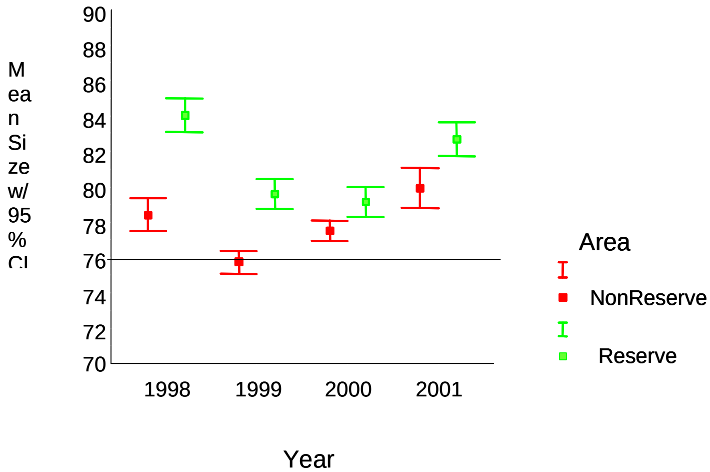
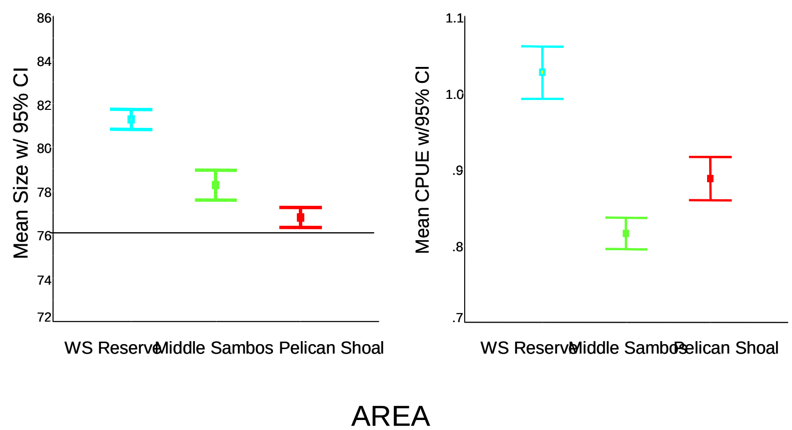


Figure 5.6 (3). Size and abundance trends among sites



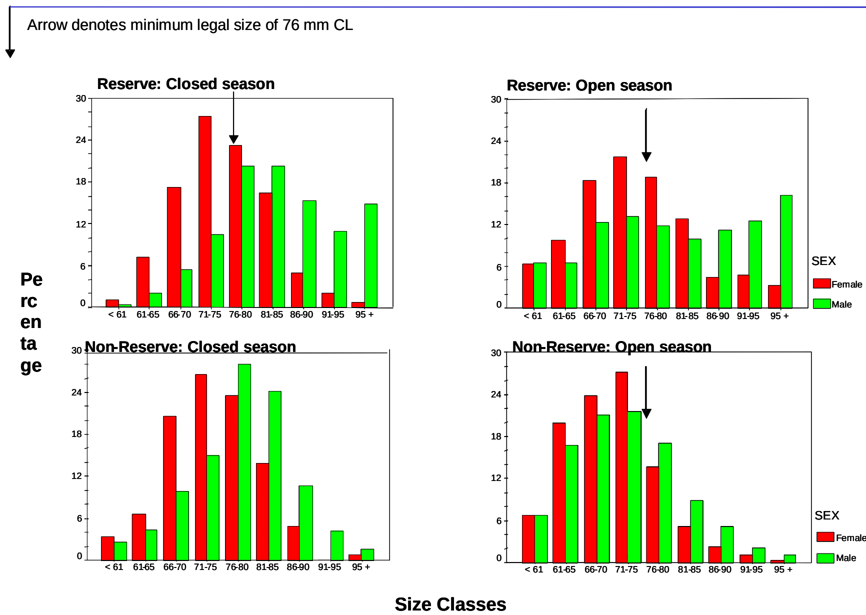
5.6.3 Sampling Intensity

Twenty-four sampling trips were conducted to sample/pull 2061 traps. A little more than half (n=1048) of the traps were empty). Each of the nine sites was sampled with 30 trap pulls (10 traps pulled three weeks in a row) in each of the closed (May-June) and open (November-December) fishing seasons for the four-year period.

Size data

A total 6992 lobsters that ranged in size from 29 to 126 mm carapace length (mean 78.4 mm) were observed during the study. Lobsters within the reserve were consistently larger than lobsters in the non-reserve areas (Figure 2). The mean size differential between reserve and non-reserve lobsters decreased over time. The mean size of lobsters were also significantly different among the three sites with a gradation in size from the largest in the reserve to the smallest in the Pelican Shoal area farthest from the reserve (Figure 3). Most of the size differential was due to differences in male size as males grow faster than females (Figure 4).

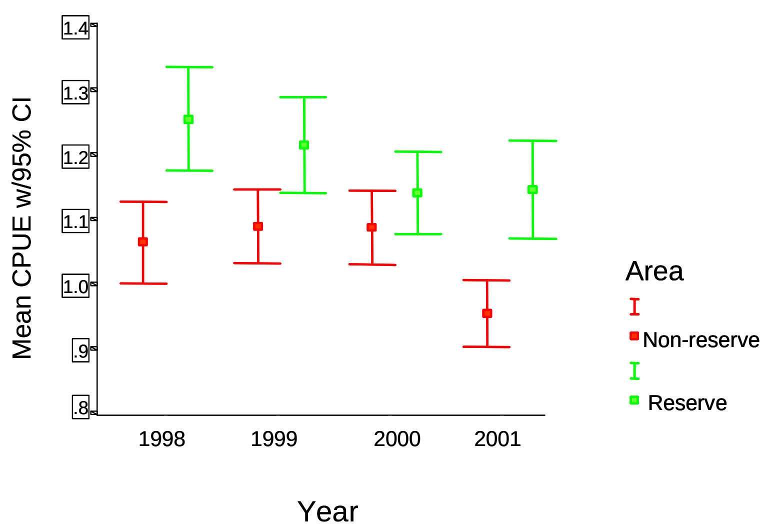
Figure 5.6 (4) Sex ratios by size and area



Catch rates

Catch per unit effort (numbers of lobster per trap pull) ranged from 0 to 38 with a mean catch rate of 3.4 lobsters per trap. The catch rate of lobsters within the reserve was greater than the non-reserve areas in most years (see Figure 5). Among areas the reserve had the highest catch rate (see Figure 4) and the Middle Sambos area—the area closest to the reserve—had the lowest overall catch rate.

Figure 5.6 (5) Relative lobster abundance differences between areas and years



5.7 DNR Assessment from 1978/79

5.7.1 Introduction

DNR conducted tag recapture studies from April of 1978 until March of 1979. A migration data set as well as a growth data set created from the animals that were recaptured exists, however the original data set that includes all animals whether they were recaptured or not has been lost. We examined the possibility of using the migration data set as a proxy for the complete data set. Including the DNR surveys from 1978/79 in a size frequency time series may be useful for stock assessment purposes.

5.7.2 Methods

Lobsters were tagged throughout the year and DNR depended on fishermen to report tagged animals in their traps in order to generate recapture data. Data collected on recaptures included: month, day, and year of initial capture and each subsequent recapture, method of capture, initial and recapture size, initial and recapture reproductive state, initial and recapture molt stage, tag number, sex, location of each capture, and notes on injuries. Growth, distance traveled, and time interval between captures was calculated from these data.

5.7.3 Results and Discussion

A size frequency graph (Lyons et al. 1981) was created using the complete data set and includes information for over 19,000 lobsters tagged during 78-79 season (Fig. 1). We created a similar size frequency graph from the migration data set, but it only uses size information for the initial capture of 3,351 animals (Fig. 2). There are some differences in the size frequencies between the complete data set and the sub-sample of animals used for the migration study. The mean size for the complete data set is 73.3 mm CL, while the mean size for the migration data set is 74.9 mm CL. The mode for the complete data set is 73 mm CL, and the mode for the migration data set is 78 mm CL. The range for the complete data set spans 22- 127 mm CL, but since the migration data set is a sub-sample made up of considerably fewer animals, it only has a range of 32-118 mm CL. Clearly the animals in the migration data set are on average larger.

Differences between the two data sets in the percent frequency caught each month for legal and sublegal sized animals are displayed in figures 3 and 4. Figure 3 shows little difference in the percent frequency of legal sized animals caught each month between the two data sets. However, a second peak in January is evident in the sublegal sized lobsters of the complete data set that doesn’t exist in the migration data set (Fig. 4). The absence of the second peak of sublegal sized animals in the migration data set may explain why the animals in the migration data set are, on average, larger than the animals in the complete data set.

A possible explanation for the discrepancy in size between the two data sets is that fishermen were more likely to report data on legal sized lobsters and return sublegal sized lobsters to the trap. The migration data set, which was made up of only animals that were recaptured, depended on the fishermen to report information equally on legal and sublegal sized lobsters in order to accurately represent the complete data set. Perhaps sublegal sized lobster recaptures went underreported. The general consensus at the SEDAR stock assessment meeting was that the remaining data could not be used for abundance but the two data sets are sufficiently similar that the migration data set is probably still useful for size-structure for the 78/79 fishing season.

Figure 5.7 (1). Complete size frequency data set from Lyons et al. 1981. Includes all tagged animals for all months during DNR 1978/79 tagging study

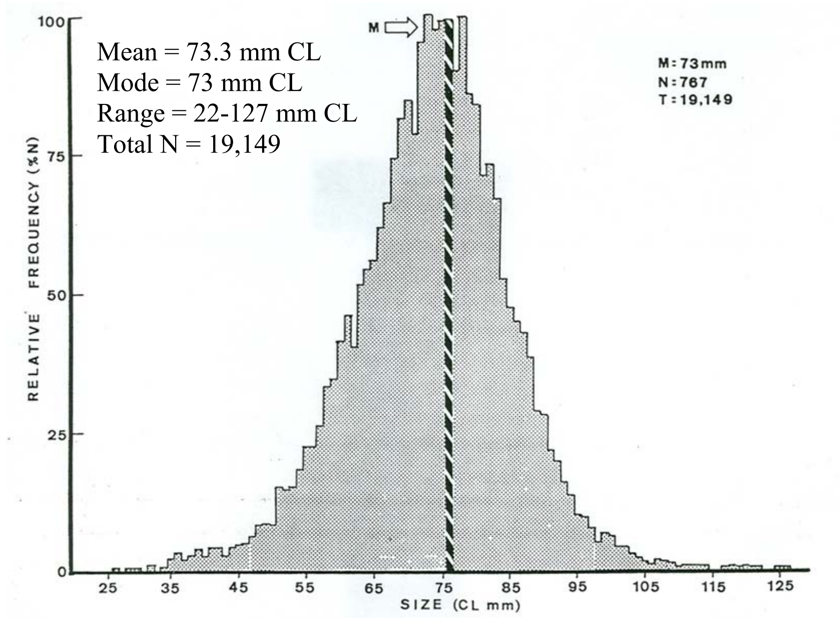


Figure 5.7 (2). Size frequency from a migration data set. Includes initial size of only animals that were recaptured during DNR 1978/79 tagging study.

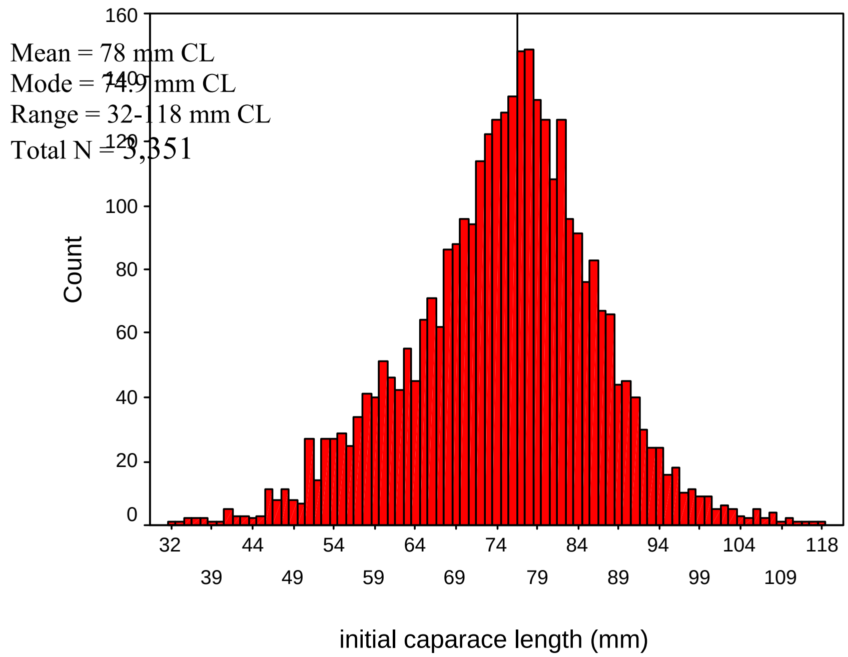


Figure 5.7 (3). Percent frequency of legal sized lobsters caught each month using data from the complete DNR 1978/79 tagging study data set (left) and the migration data set (right), which includes only animals that were recaptured.

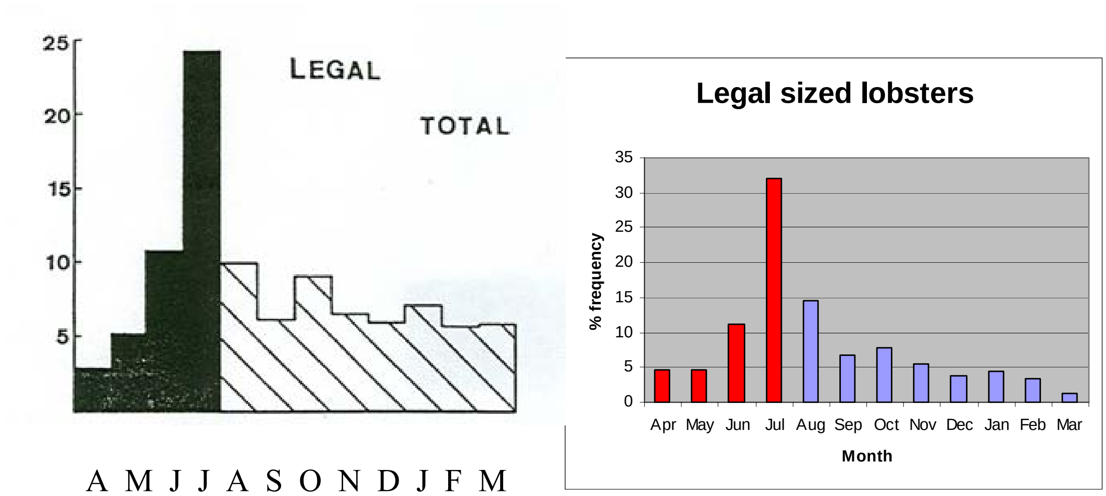
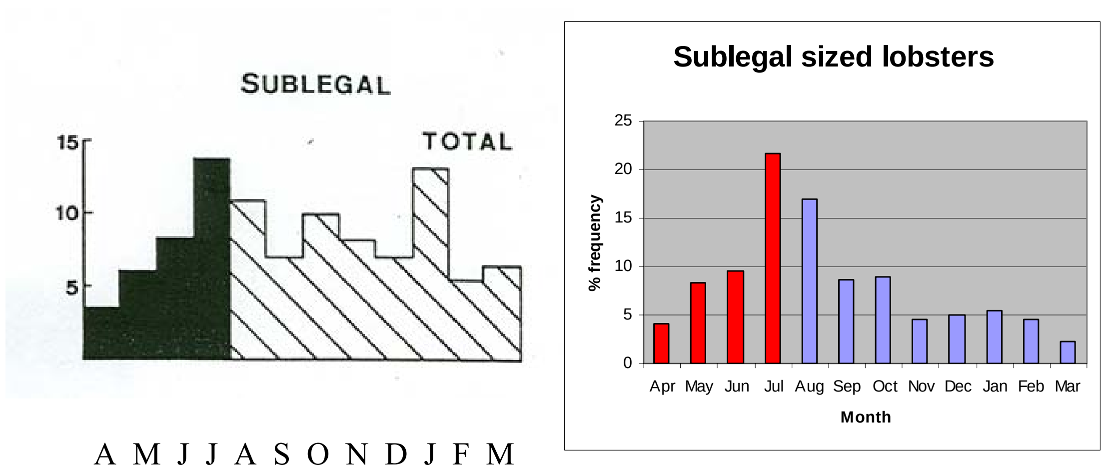


Figure 5.7 (4). Percent frequency of sublegal sized lobsters caught each month using data from the complete DNR 1978/79 tagging study data set (left) and the migration data set (right), which includes only animals that were recaptured.



5.8 UFL Lower Keys Surveys 1975/76

5.8.1 Introduction

At the request of the commercial spiny lobster fishery in 1974 Florida Sea Grant conducted a series of informational workshops to determine the status of research and to identify research needs. Subsequently, Florida Sea Grant funded a tag and recapture program in the Lower Florida Keys conducted by the local Sea Grant Extension Agent. The tagging project was conducted from June 1975 through August 1976. The title of the project was *Two-Year Lower Florida Keys Spiny Lobster Fishery Tag-Recapture Project*
And the principal investigator was Douglas Gregory.

5.8.2 Methods

Spiny lobsters were captured with b aited, commercial wooden-slat traps that were placed in five different habitats in the lower Florida Keys (Fig. 1). Two trapping sites were located in the Gulf of Mexico and three in the Atlantic Ocean. Site 1 (Gulf middepth) was located in 7-9 m of water on a hard, flat substrate overlain with sand, typified by a fauna of scattered sponges and small corals; site 2 (Gulf shallows) was in 4-6 m on sand-grass flats with numerous sponges; site 3 (Atlantic shallows) was in 5-6 m on sand-mud-grass flats with scattered coral heads; site 4 (Atlantic patch reef) was in 7-12 m on patch reefs interspersed with sand-grass flats; and site 5 (Atlantic deep reef) was in 12-27 m on the seaward edge of the offshore reef. Twenty-five traps, placed at 250-m intervals in a five by five grid (1-km^2 area), were used to sample each site. Sites 1-4 were sampled weekly for 14 months, July 1975-August 1976; site 5 was sampled weekly for 5 months, April-August 1976. Each spiny lobster was tagged with a numbered Floy FD-68B tag, measured for carapace length (to nearest 0.1 mm), and examined for sex and reproductive condition.

After capture and tagging, all legal spiny lobsters were released into open water, whereas all sublegal lobsters were replaced in the trap in which they were captured to test the hypothesis that sublegal lobsters retained in the traps function as "bait" to attract legal lobsters. For analysis, a captured spiny lobster was considered a valid observation if it was (1) an initial capture, (2) a recaptured legal lobster, or (3) a recaptured sublegal lobster that had changed trap residences between successive observation periods; recaptures constituted 9% of all valid observations.

Figure 5.8 (1) Study sites

576 GREGORY ET AL.

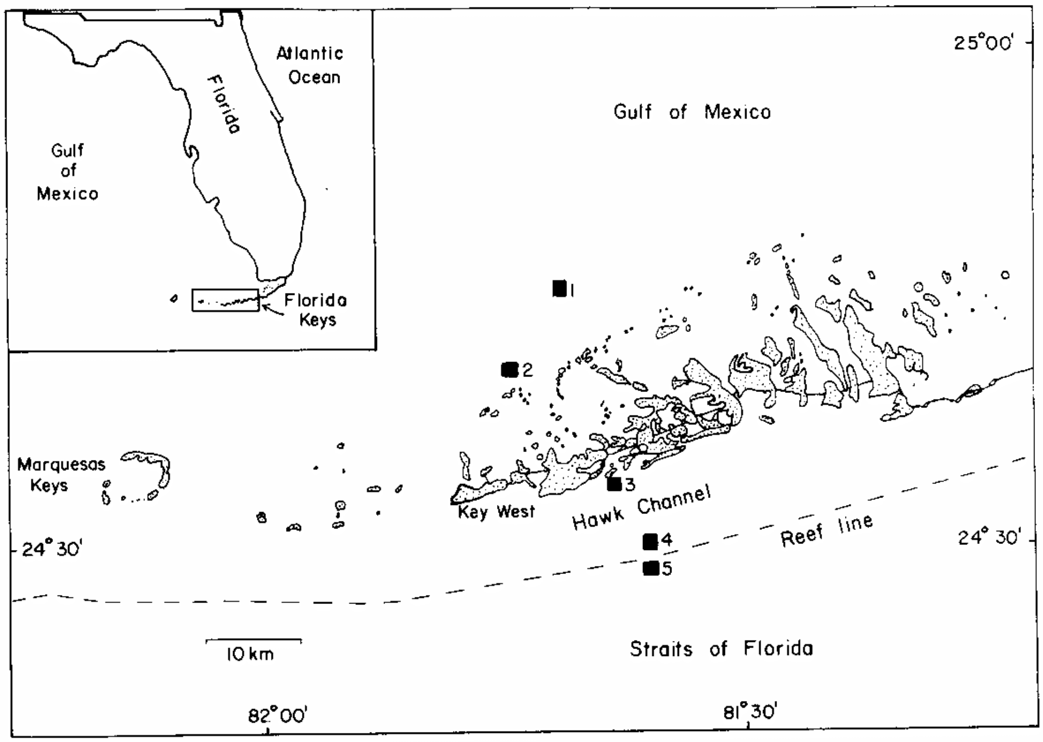


FIGURE 1.—*Location of 1-km² trapping sites for spiny lobsters in the lower Florida Keys, 1975–1976. Site 1 = Gulf middepth; site 2 = Gulf shallows; site 3 = Atlantic shallows; site 4 = Atlantic patch reef; site 5 = Atlantic deep reef.*

5.7.3 Sampling Intensity

A total of 4313 lobsters were observed from 2840 traps pulled on 112 sampling trips conducted during the June 1975 – August 1976 period (see Tables 1 and 2). Each of the five sample sites were sampled with 25 commercial lobster traps that were sampled weekly, weather permitting. Although similar numbers of lobsters were tagged throughout the year the majority of the tag returns from the fishery were collected during the first few months of the fishing season (Figure 2).

Figure 5.7 (2). Percent Frequency distributions

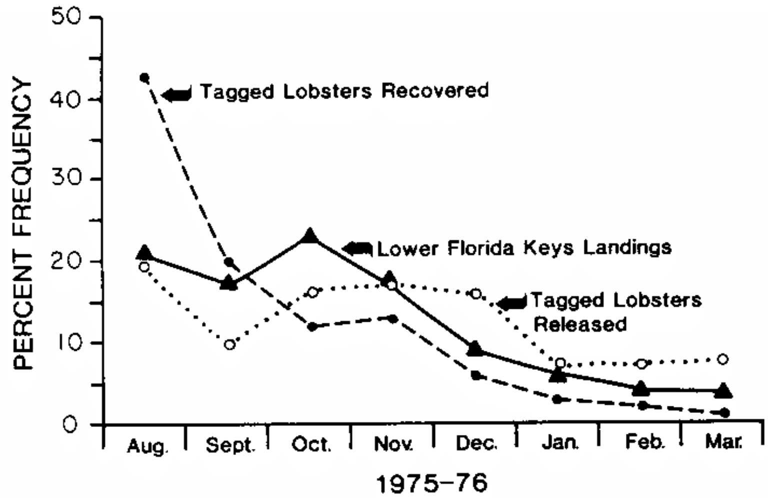
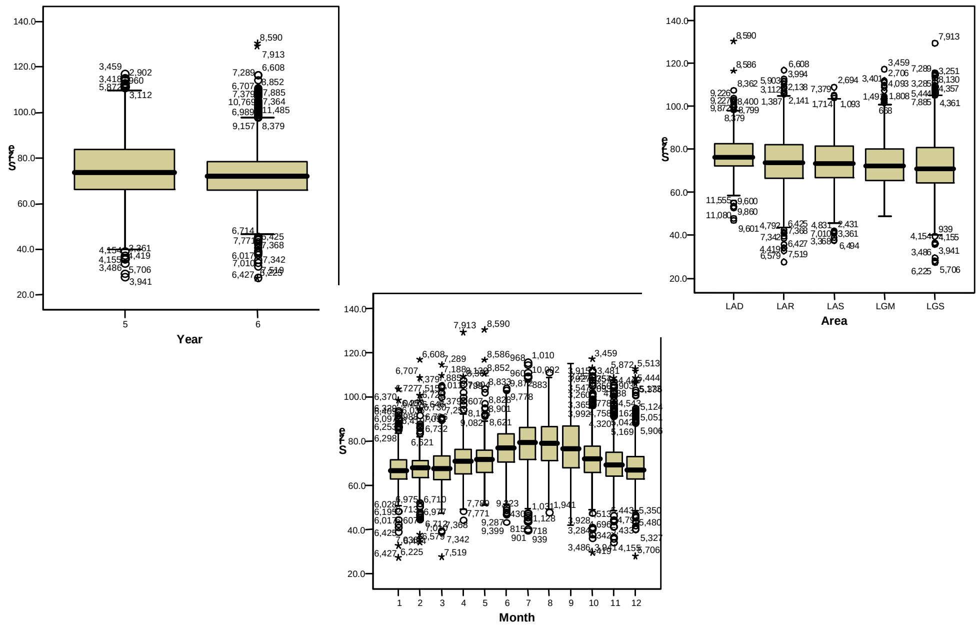


FIG. 2. Monthly percent frequency distribution of tagged lobsters released (N = 2689), tagged lobsters recovered (N = 543), and commercial landings (850 metric tons) in the lower Florida Keys, August 1975 – March 1976.

5.7.4 Size data

A total 8722 lobsters that ranged in s ize from 27 to 130 mm carapace length (mean 73.9 mm) were observed during the study. The sizes of lobsters did not vary much by year or area but did exhibit a seasonal trend with larger sizes accumulating during the closed fishing season (Figure 3).

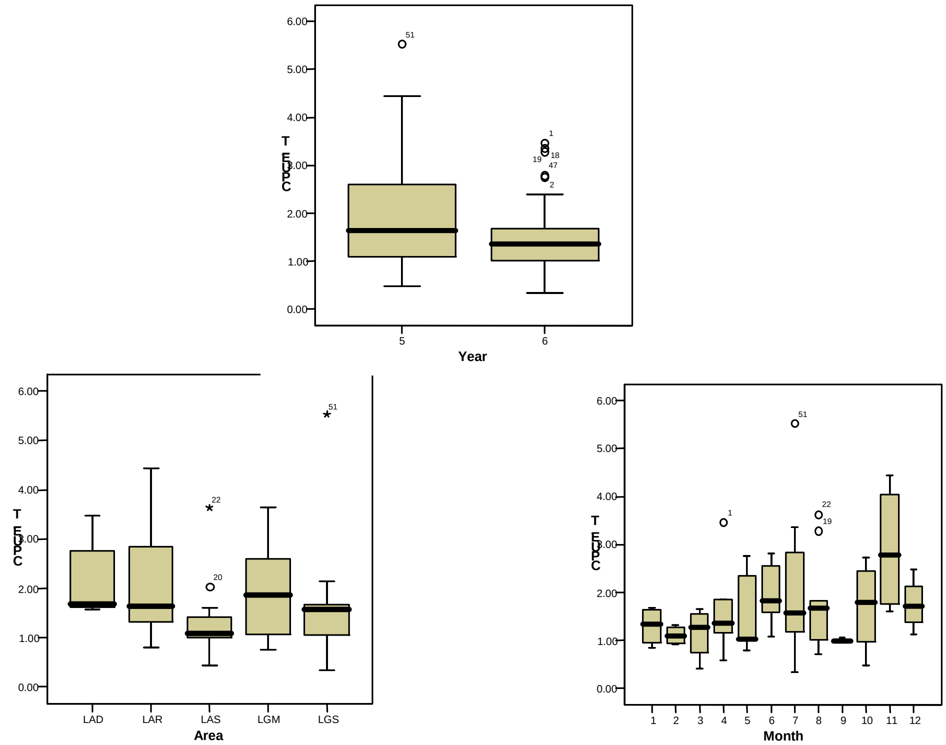
Figure 5.7 (3). Summary of length frequencies by Year, Month and Area



5.7.5 Catch rates

Gross trends catch per unit effort terms in terms of catch per trap pull are summarized in Figure 4 below. Overall catch rates in 1976 were lower than in 1975. The Atlantic Shallows area had the lowest overall catch rates while the Gulf Mid-depth had the highest. Catch rates by month generally increased from January through August, were greatly reduced in September and increased again during October through December.

Figure 5.7 (4). Catch per Trap by year, sample area and month. (LAD=Lower Keys Atlantic Deep Reef; LAR=Lower Keys Reef Patches; LAS=Lower Keys Atlantic Shallows; LGM=Lower Keys Gulf Mid-depth; LGS=Lower Keys Gulf Shallows)



Growth of Tagged Lobsters

The growth of tagged lobsters was variable (see Figures 5 and 6). Growth increments was greater in males than females. Growth increments were lower in the reef areas (Atlantic Deep and Reef sites) than in the non-reef areas (Atlantic and Gulf Shallows and Gulf Mid-depth).

Figure 5. Growth increment (Gabs) of recaptures by size of initial capture

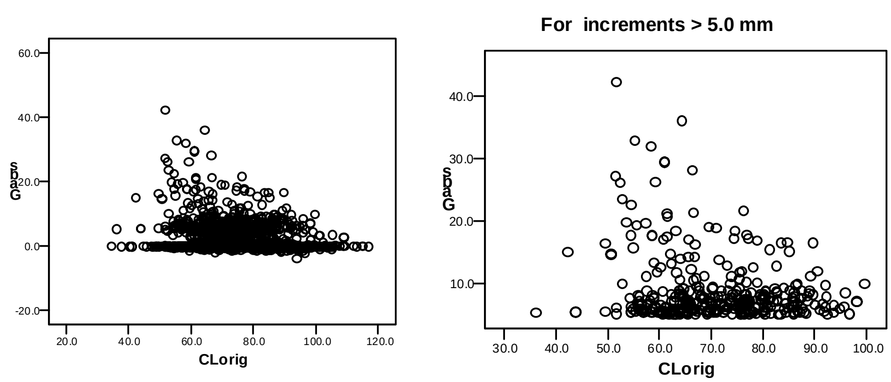


Figure 5.8 (6). Absolute growth increments for tagged lobsters recaptured between 30 and 90 days at large.

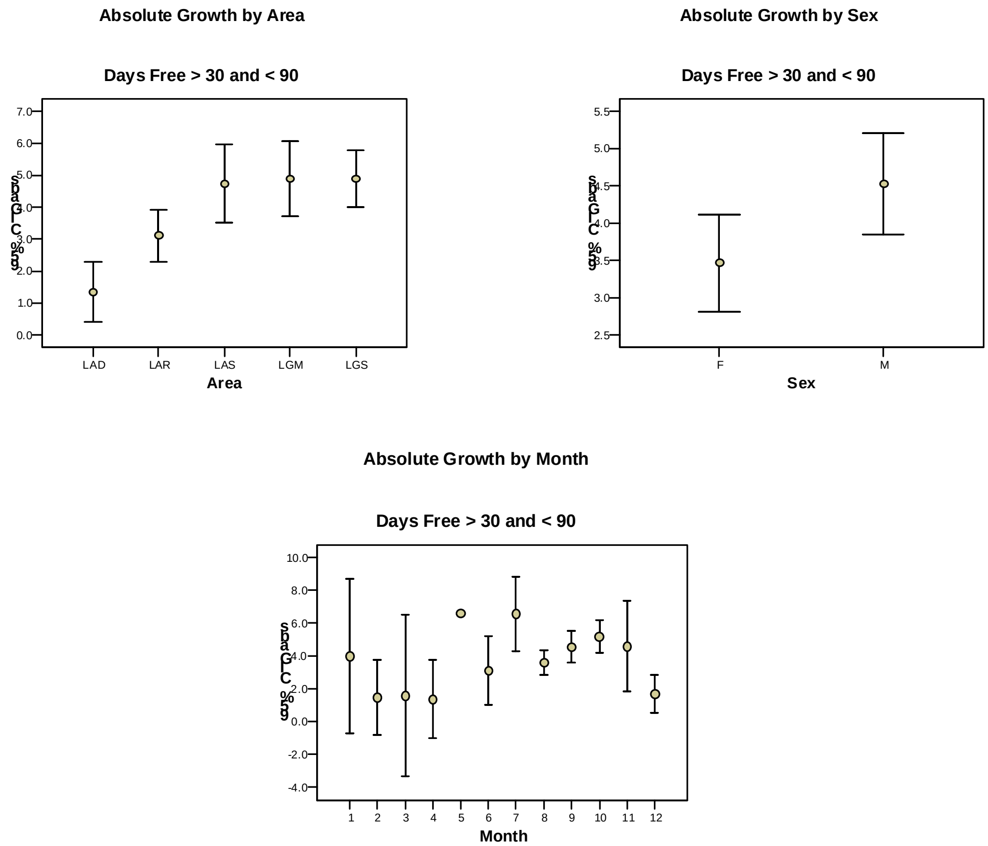


Table 5.8 (1). Trap samples.

Number ofTraps Sampled by Year, Month, and Area

Year	Month	Area LAD	LAR	LAS	LGM	LGS	Total
1975	6			32	63	60	155
	7		115	120	108	59	402
	8		114	71	82	80	347
	9		98	82	123	147	450
	10		138	125	98	102	463
	11		49	50	73	78	250
	12		122	122	123	130	497
	Totals		636	602	670	656	2564
1976	1		97	100	50	51	298
	2		96	100	74	76	346
	3		50	75	99	100	324
	4	43	75	70	97	100	385
	5	41	64	50	76	69	300
	6	93	61	75	80	79	388
	7	45	97	97	97	100	436
	8	69	73	73	74	74	363
	Totals	291	613	640	647	649	2840

5.9 Mini-Season Dive Surveys

We measured the impact of the recreational mini-season on the Caribbean spiny lobster (*Panulirus argus*) in the Great White Heron National Wildlife Refuge (GWHNWR) in the Florida Keys during 2002. Visual SCUBA diver surveys were used to quantify distribution, abundance and size-structure of spiny lobsters at nine locations in the GWHNWR immediately before and after the 2 d mini-season. We conducted surveys in two distinct habitat types: (i) patch reefs and (ii) patch-heads. Patch reefs are generally located along the NE-SW axis of the northern border of the GWHNWR and are composed of exposed rock, soft and hard coral, sponge, and ledge habitats of 0.5 – 1.0 m relief. Patch heads are common within the protected interior of the GWHNWR and consist of relatively small (1-3 m), discrete clusters of hard corals surrounded by shallow seagrass beds. Recreational diver fishing pressure was estimated by counting the number of boats anchored at each site, and was used to assess the relationship between fishing effort and lobster density.

Overall, 95 and 79% of lobsters were removed from patch reef and patch heads, respectively, during the recreational mini-season. Fishing effort (no. of boats) was 900 times greater during the mini-season than during the regular fishing season (~3 weeks later). Fishing effort was 10 times greater on patch heads than on patch reefs, probably due to higher densities (~100-fold) of lobsters in patch-head habitats. Of major concern is the extremely high rate of exploitation (~90%) of lobsters by recreational fishermen. The proportion of lobsters removed in both habitats, however, was independent of lobster density. Thus, management actions that reduce diver effort during the recreational mini-season can be expected to reduce harvest.

6.0 Tuning Indices

6.1 Introduction

Indices that are believed to represent the dynamics in the underlying stock assist the mathematical population models in achieving 'reasonable' solutions. The process of fitting a model to data is for the model to vary the parameter values and, ultimately, identify a unique set that minimizes the differences between observed and calculated values. Tuning indices provide observed values to the model: for each index the model identifies a parameter (catchability coefficient) that relates the index to the population and a selectivity pattern, because an index usually represents only a portion of the population, and then with the catchability coefficient and the selectivity, the model calculates predicted values.

ndices can be divided into two groups based on whether the information comes from the fishery (fishery dependent) or from scientific surveys (fishery independent). With spiny lobsters, there are two fishery dependent sources: number of lobsters per trap from FWC's observer program that was conducted from 1993-94 through the 2000-01 fishing years and the number of lobsters landed per person during the sport season from Biscayne National Park's creel survey which has been conducted annually since 1976. Fishery independent surveys include the number of pueruli and first-stage juveniles per collector from Big Munson (beginning in 1986) and Long Key (beginning in 1994), the number of lobsters per 60-minute search from FWC's adult monitoring program since 1997, the number of lobsters per trap from the Sentinel project that was conducted from 1998 through

2001, and the number of juveniles observed during dives by Old Dominion and FWC personnel from 1988 through 2004.

6.2 Methods

Maunder and Punt (2004) recently reviewed the methods for standardizing indices. The spiny lobster indices all were in numbers of lobsters and the indices were standardized using generalized linear models (GLM) using a Poisson distribution with a log link. In addition to year or fishing year, potential explanatory variables included month, area, soak time, habitat, or open and closed fishing seasons. The process of identifying which variables to include for an index was to first calculate the mean deviance (deviance divided by the appropriate degrees of freedom) of the index without any explanatory variables and then to calculate the index as a function of each variable separately. The next step was to take the variable that explained the highest proportion of the mean deviance and pair that variable with all of the remaining variables, to identify the next variable to include in the model. Following the recommendation of the SEDAR 04 Review Panel in 2003, this process was repeated until no more variables explained at least 0.5% of the mean deviance. As noted in Maunder and Punt (2004), this procedure results in fewer variables being included in the model than using the significance of the Type-3 Sum of Squares to select variables. The statistical approach includes terms that are significant because of the large number of observations in most of the indices but only explain minute portions of the uncertainty.

6.3 Results and Discussion

6.3.1 Fishery Dependent Indices

The observer data was used to generate two indices: legal-sized lobsters which are those lobsters with carapace lengths of 76.2 mm (3 inches) or greater and an index of lobsters that are believed to recruit into the fishery during a given fishing year. These pre-recruit lobsters have carapace lengths between 68 mm and 76 mm. The original observer index values truncated the data set to hauls that had soak times of 50 days or less; however, participants at the Data Workshop recommended including all hauls (96,762) but categorizing soak into a few categories. We put soak time into four categories: 1-7 days, 8-14 days, 15-28 days, and more than 28 days. The participants also recommended including the number of lobsters used as bait as another potential explanatory variable. Neither soak time nor the number of short lobsters baiting the trap met the 0.5% criterion in the legal-sized index and the GLM explained 7.1% of the deviance (Fig. 1).

The pre-recruit index was developed in the same way as the legal-sized index. However, with pre-recruits the main explanatory variable was the number of lobsters used as bait (9.6% of the total deviance) followed by area (3.9%) and fishing year (1.2%). A possible explanation for the number of bait lobsters being significant is that some of the sub-legal lobsters observed in the trap were the same lobsters that were used to bait the trap when the trap was set. The final GLM explained 14.7% of the deviance (Fig. 2).

The Biscayne National Park index is the number of lobsters landed per person from the recreational Sport Season in July. These data were collected as part of the Park Service's creel survey that began in 1976. While this index covers 29 years; management has changed bag limits over those years. In 1987, the then Marine Fisheries Commission instituted a six lobsters per person bag limit or a 24 lobster boat limit, in 1992 the commission raised the bag limit to 12 lobsters outside of Monroe county, and in 2003 the commission eliminated the 24 lobster boat limit statewide and lowered the bag limit in Biscayne National Park back to six lobsters per person. The 12-lobster-per-person bag limit did not appear to have any effect when compared to the no bag limit time period other than a few extra trips with 12 lobster per person. Several variations of the index were calculated but Carl Walters (personal communication) recommended using the number of lobsters per person because the number per person had already declined before the 6-lobster per person bag limit was implemented and similarly the decline after 1999 occurred even with the 12-lobster per person bag limit (Fig 3.).

6.3.2 Fishery Independent Indices

Phillips found that settlement of pueruli could be used to predict the total catch of western rock lobsters in western Australia four years later (1986). FWC has monitored the settlement of pueruli at Big Munson Key since 1987 and Long Key since 1994 with 'Witham' collectors. Collectors have been placed in other areas in Florida but these two locations have been monitored the most consistently. The index is the number of pueruli per collector that were sampled sometime during days five through 13 after the new moon from Big Munson and Long Key. The standardization process also used a GLM with a Poisson distribution and log link and explanatory variables such as month, lunar day, location in addition to fishing year. Soak time was not included because it was not recorded in the Long Key data set. The GLM accounted for 38.9% of the puerulus deviance with month (26.5%), fishing year (7.8%), Location (3.6%), and lunar day (1.9%) and the index is shown in Figure 4.

As part of a Florida Keys Marine Sanctuary study, FWC conducted dives in Sanctuary Protected Areas (SPA) and in nearby areas and one aspect of the study focused on monitoring adult lobster densities. One SPA near Key West (Western Sambo and its nearby area Pelican Shoals) has continued to be sampled after the completion of study in 2001. The protocol was for one diver to conduct a 60-minute search and mark each lobster den and another diver captured the lobsters to measure and sex them. We developed two indices from these data: pre-recruit (68-76 mm CL) and legal-sized lobsters (CL>76 mm). As with the other indices, we used GLMs to standardize the indices with habitat (fore reef, back reef, and offshore patch reef) and site (Western Sambo and Pelican Shoals) in addition to year. For pre-recruit lobsters (Fig. 5a), only habitat (18.7%) and year (7.6%) were significant in explaining variations in the number of lobsters per dive while for legal-sized lobsters (Fig. 5b) all of the variables were significant: habitat (9.4%), year (4.4%), and site (2.9%).

The Sentinel Lobster Fisheries Project set 10 traps in three areas and three habitats in each area during both the closed and open seasons. These traps were pulled five times during the closed season and during the open season. As with FWC's adult monitoring, we created two indices from these data: pre-recruit and legal-sized lobsters. We used GLMs to standardize the indices for habitat (inshore, channel, and reef), area (Western Sambo Reserve, Middle Sambos, and Pelican Shoal), and season (closed --May or June and open -- November or December). The pre-recruit index (Fig. 6a) only explained a small portion of the deviance in number per trap (10.9%). Area (7.7%) and year (3.2%) were the only variables that met the 0.5% criterion for being included in the model. In the index for legal-sized lobsters (Fig. 6b), area (19.9%), habitat (5.4%), and season (1.3%) were included in the model. Year was included following the recommendation of Maunder and Punt (2004) even though year only explained 0.4% of the deviance. If year is not included, then the index would be a flat line.

The last fishery-independent index was the composite index developed by Mark Butler and Tom Dolan at Old Dominion University. They compiled records of all their juvenile surveys from natural hard-bottom sites and selected only juveniles in the size range of 25-45 mm CL, the data were further subset to just the Middle Keys (81.3^{o} W - 80.7^{o}W). To eliminate the time spent capturing, they assumed a handling time of 15 seconds per lobster), the final cut was for surveys conducted during the summer (May-September). The index shows a decline from 1988 until the late 1990s and then quite variable but generally increasing (Figure 7).

Table 1 and Figure 8 compare the different indices. The indices for legal-size lobsters showed a general increase reaching a peak in 1999 and a decrease. The adult monitoring index from diving and the Sentinel index based on traps were very similar as expected because they were both conducted in the same area -- Western Sambo Reserve and Pelican Shoal. The pre-recruit indices also show similar patterns. When the puerulus index is plotted with ODU juvenile index the one year later they both show more lobsters in later years but also more variable (Fig. 9).

Table 6.0 (1). Potential indices for tuning the stock assessment. BNP is Biscayne National Park creel survey and ODU Juv is the juvenile index developed at Old Dominion University.

	Fishery dependent			Fishery independent					Pueruli
				Legal-sized			Pre-recruit		
FY	Legal-sized Observer	Pre-recruit Observer	BNP	Adult Monitoring	Sentinel	ODU Juv	Adult Monitoring	Sentinel	FWC
1986			8.68						
1987			9.12						11.55
1988			10.00			0.227			11.43
1989			10.02			0.205			16.03
1990			8.69			0.113			13.18
1991			12.15						14.62
1992			9.91			0.090			11.32
1993	0.70	0.98	15.86			0.120			13.30
1994	1.14	1.26	12.04			0.035			14.44
1995	1.00	1.11	15.06			0.070			15.41
1996	1.08	1.39	12.42			0.093			18.32
1997	1.27	1.61	21.07	11.21		0.075	6.64		21.42
1998	1.08	1.18	15.78	11.45	1.14	0.072	4.32	0.60	25.07
1999	0.93	1.37	27.29	21.88	1.43	0.138	9.86	1.15	22.81
2000	0.86	1.16	14.92	23.05	1.50	0.044	9.90	0.86	23.84
2001			9.44	17.36	1.21	0.118	4.62	0.56	17.63
2002			14.33	14.32		0.064	5.35		22.85
2003			11.71	19.60		0.121	5.11		15.60
2004			15.91			0.190			

Figure 6.0 (1). Standardized number of legal-sized lobsters per trap from FWC's observer program by fishing year. The verical lines are the 95%-confidence intervals, the horizontal lines are the medians from 1000 Monte Carlo simulations, and the numbers above are the number of trap hauls per fishing year.

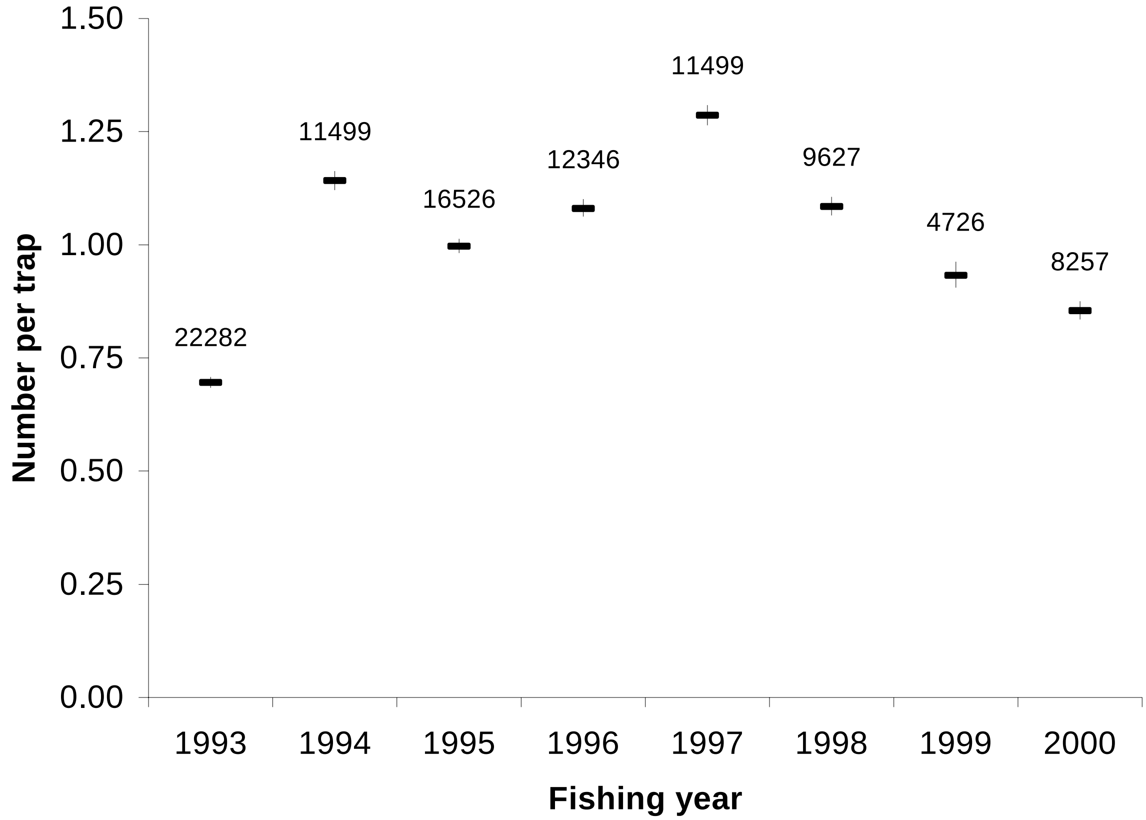


Figure 6.0 (2). Standardized number of pre-recruit lobsters (68-76 mm CL) per trap from FWC's observer program by fishing year. The vertical lines are the 95%-confidence intervals, the horizontal lines are the medians from 1000 Monte Carlo simulations, and the numbers above are the number of trap hauls per fishing year.

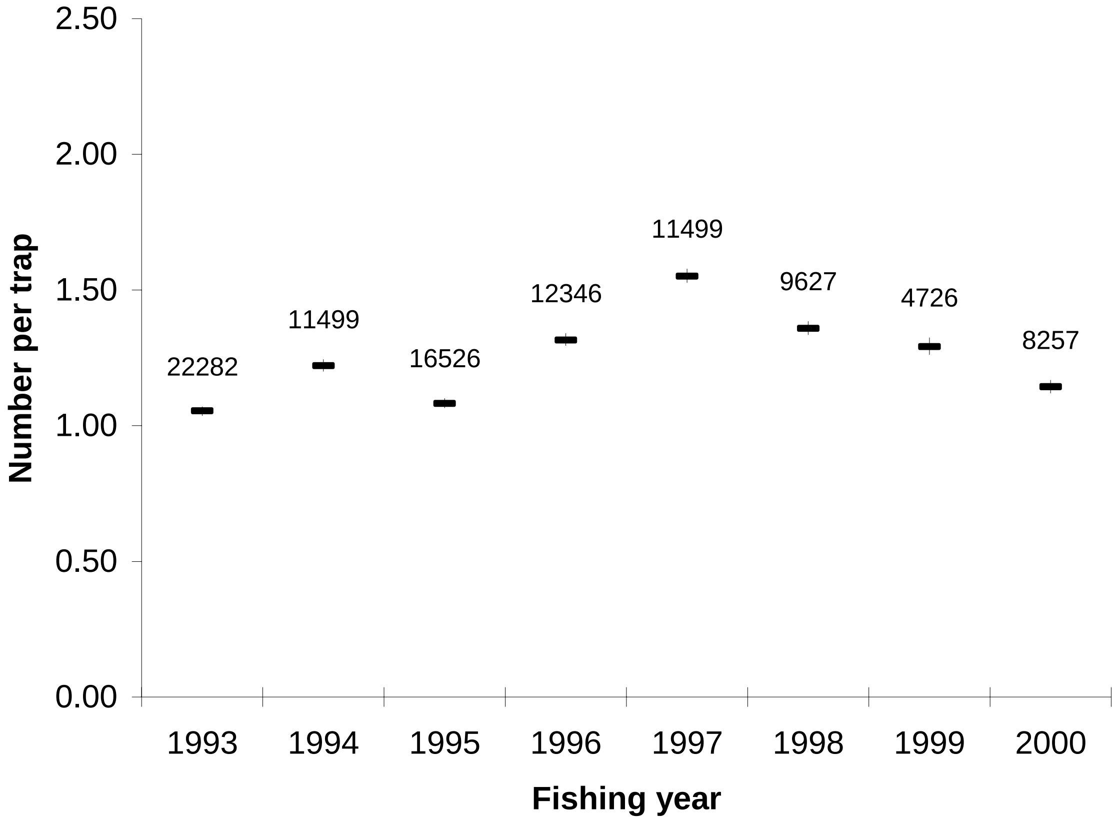


Figure 6.0 (3). Relative number of lobsters per person from Biscayne National Park's creel survey (raw means), proportion of trips with at least six lobsters per person (median proportion), or number of lobsters per person (mean number per person). To facilitate comparisons, all of these indices have been scaled to their means.

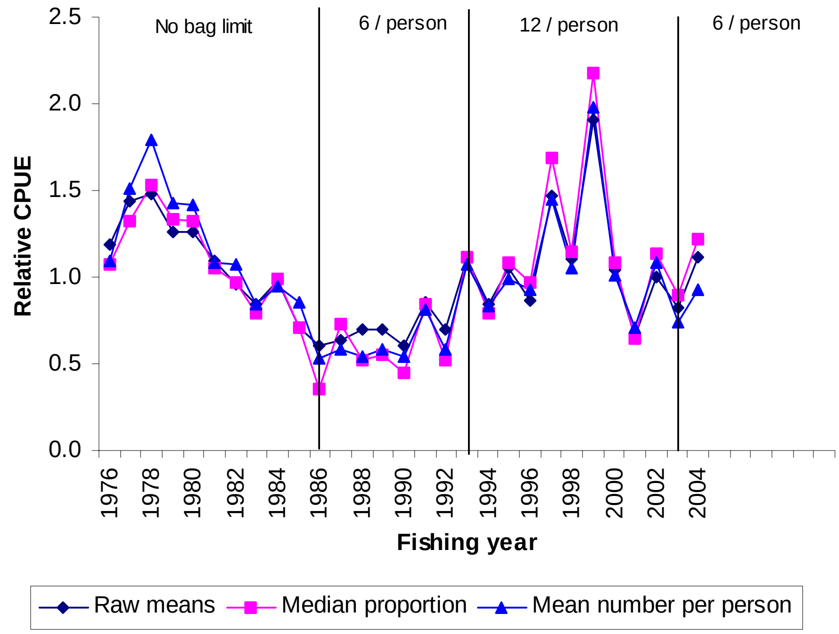


Figure 6.0 (4). The standardized number of pueruli per collector by fishing year from Big Munson Key and Long Key. The vertical lines are the 95%-confidence intervals, the horizontal lines are the medians from 1000 Monte Carlo simulations, and the numbers above are the number of collector examined per fishing year.

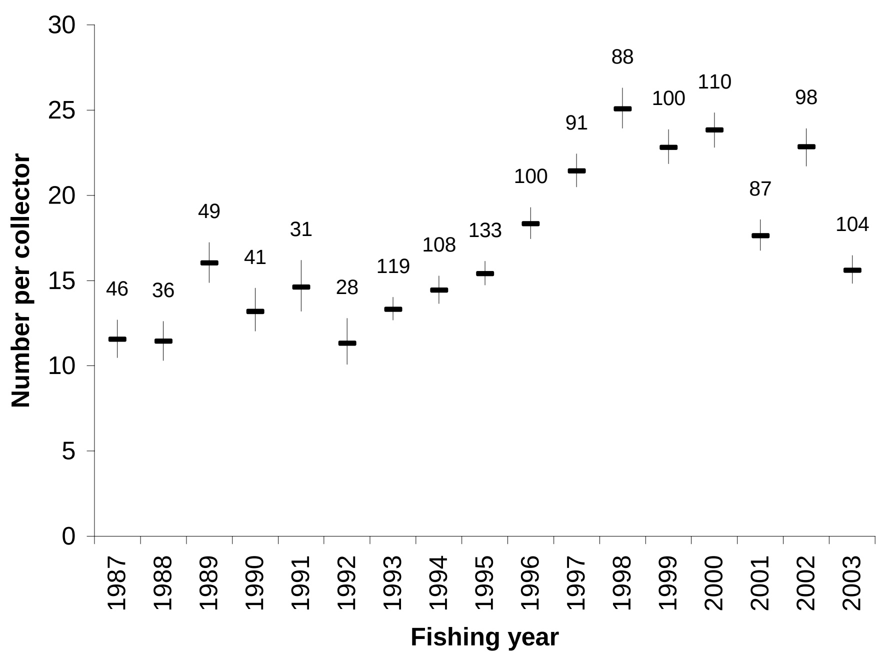
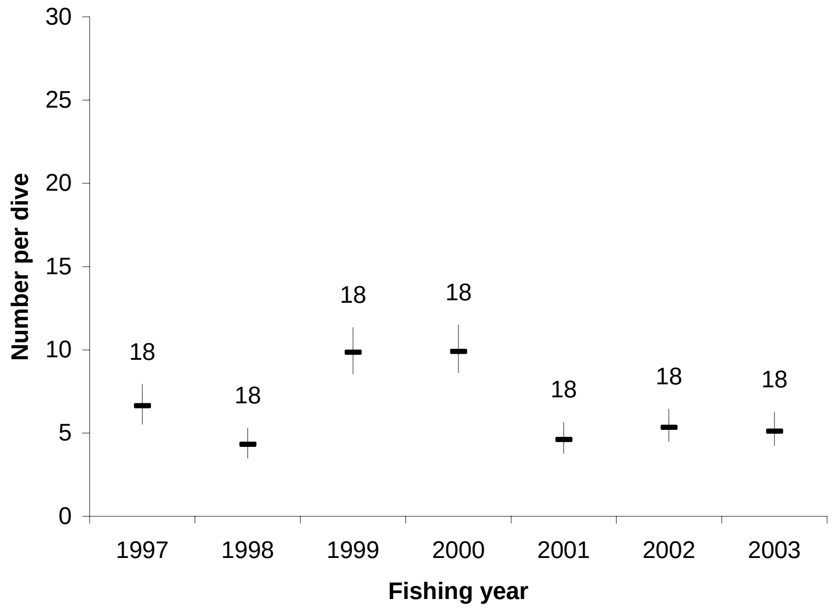


Figure 6.0 (5). The standardized number of pre-recruit lobsters (68-76 mm CL, a.) and legal-sized lobsters (CL > 76 mm b.) per 60-minute search dive from FWC's adult monitoring at Western Sambo and Pelican Shoal. The vertical lines are the 95%-confidence intervals, the horizontal lines are the medians from 1000 Monte Carlo simulations, and the numbers above are the number of collector examined per fishing year.

a. Pre-recruit lobsters



b. Legal lobsters

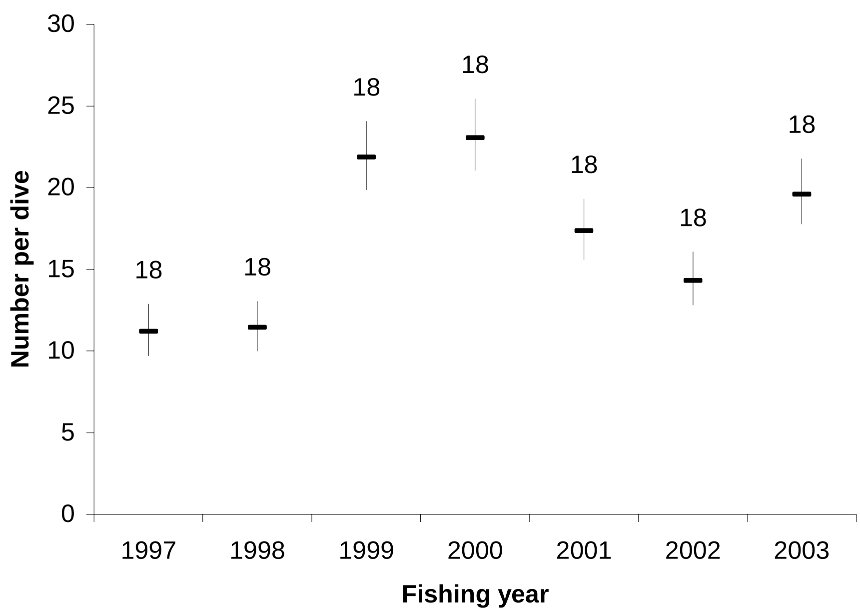
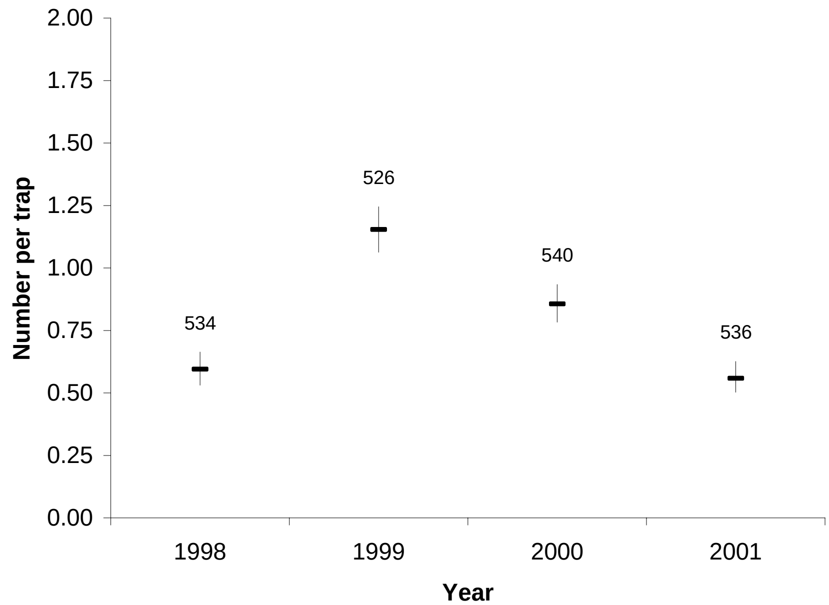


Figure 6.0 (6). The standardized number of (a) pre-recruit lobsters (68-76 mm CL) and (b) legal-sized lobsters (CL > 76 mm, b) per trap from the Sentinel Lobster Fisheries Project. The vertical lines are the 95%-confidence intervals, the horizontal lines are the medians from 1000 Monte Carlo simulations, and the numbers above are the number of traps examined per year.

a. Pre-recruit lobsters



b. Legal lobsters

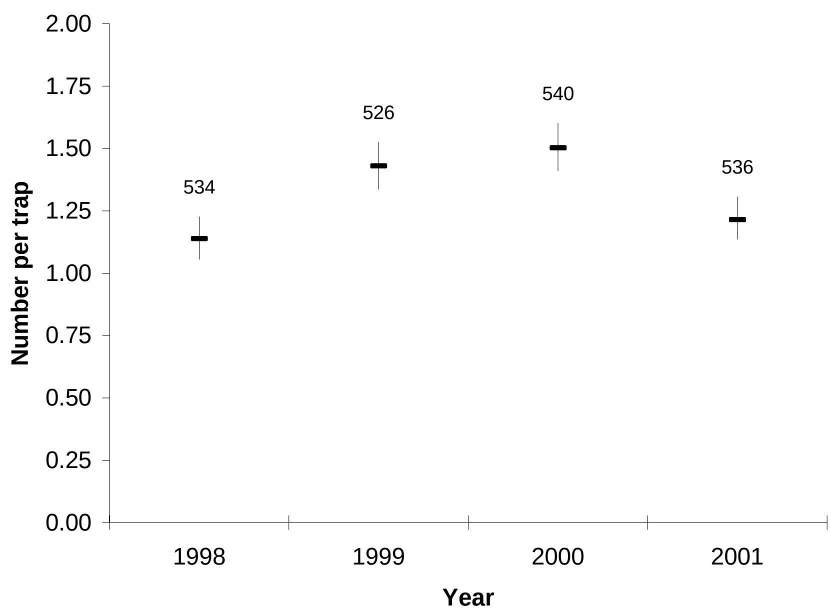


Figure 6.0 (7). The number of juvenile lobsters (25-45 mm CL) per one minute search in the Middle Keys from Old Dominion University.

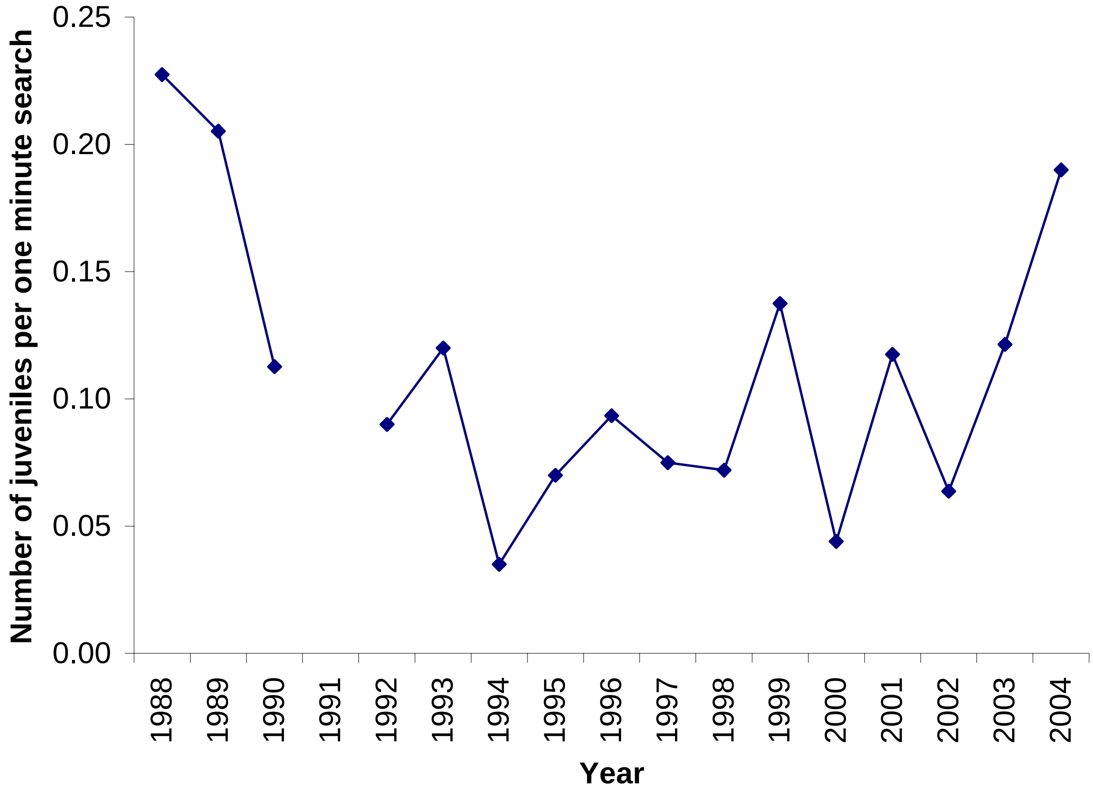
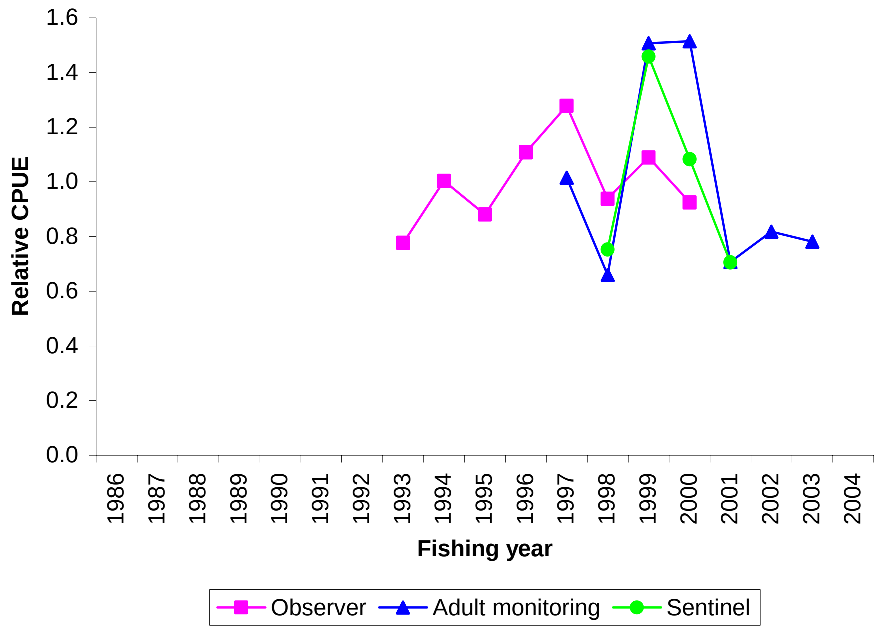


Figure 6.0 (8). Comparison of potential tuning indices.

a. Pre-recruits lobsters



b. Legal-sized lobsters

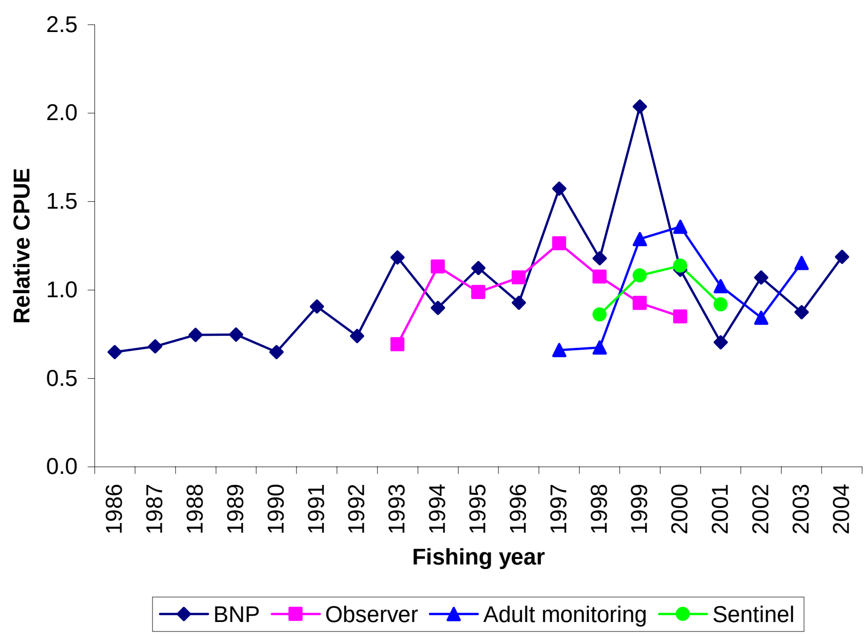
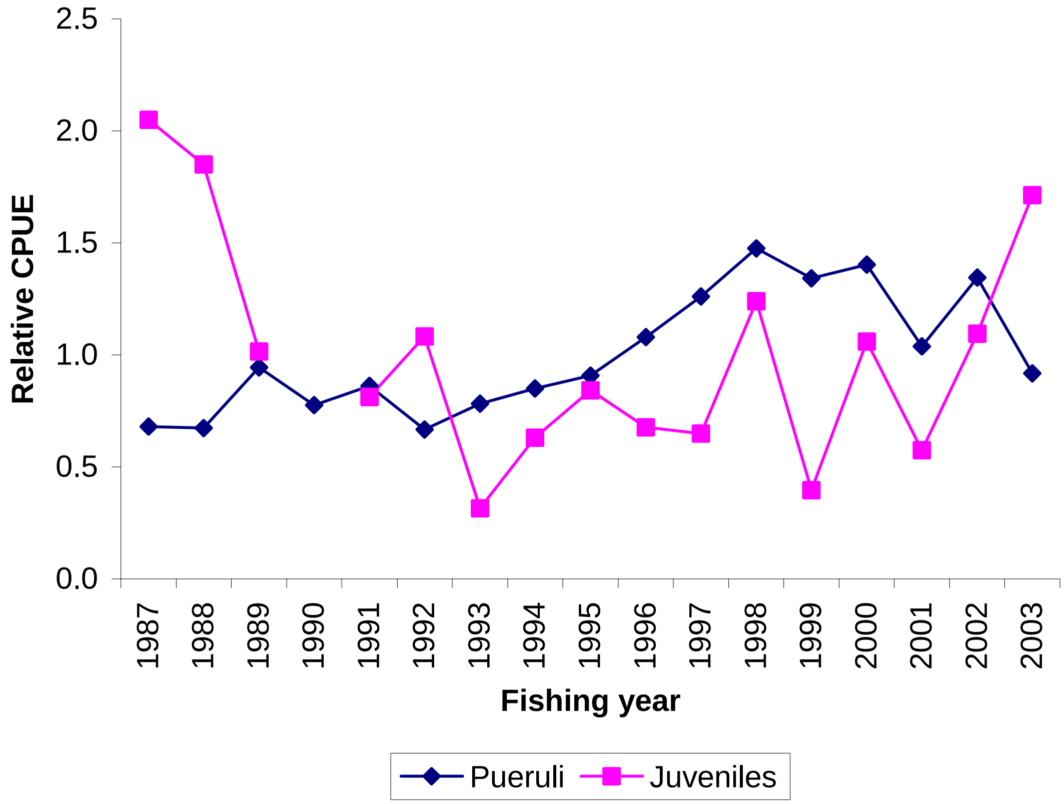


Figure 6.0 (9). Comparison of number of pueruli per collector and the number of juvenile lobsters from the Middle Keys one year later. The year in the plot is the settlement year and the juveniles are from one year later.



7.0 Review of Past Assessments

The early researchers deserve credit for making the most of the data available to them. Robinson and Dimitriou (1963) looked at trends in total catches, catch per unit effort where effort was measured in the number of fishing permits, man-days, eleven selected fishermen, and trap-days from a dealer in Key West. Most of the effort data was from the period 1959-60 through 1962-63. They concluded that the declining trends reflected more traps sharing a stable quantity of lobsters. They also noted that most fishermen believe that so much effort is being applied to the fishery that profitable fishing is becoming increasingly rare.

Powers and Thompson (1986) focused on the west coast fishery including the Florida Keys. They noted that the effective fishing season had contracted i.e., more of the landings occurred in August and September, and they evaluated the effects of using shorts as bait with yield per recruit analysis. They concluded that landings and recruitment had been variable without trends even though mortality rates were high.

Powers and Sutherland (1989) examined the monthly patterns of landings and noted the sharp drop-off in landings as the season progressed. They assumed a within season relative fishing mortality rate of 1.0 during weeks 1-22 (beginning of the season through December) then a linear decline to 0.5 by the end of March and zero for April - July. Their conclusions were that the fishery operated primarily on the recruiting lobsters indicating high fishing mortality rates and that the fishery is fully exploited. They also conclude that there does not appear to be any trend in recruitment.

Muller et al. (1997) used a different approach from the earlier assessments that combined length frequency information with landings, a growth model based tagging data to model the probability of molting and the subsequent change in size, and a statistical catch-at-age model (Integrated Catch at Age, Patterson and Melvin1996) to estimate population size and fishing mortality rates by sex for the upper and lower Keys. With a natural mortality rate of 0.3 per year, the fishing mortality rates on females in the upper Keys ranged from 1.27 per year to 0.31 per year, the corresponding spawning potential ratios (SPR) ranged from 9% to 23% while the fishing mortality rates in the lower Keys were less than half those of the upper Keys ranging from 0.54 per year to 0.21 per year and SPR values ranged from 23% to 34%. They also noted that a pre-recruit and an index of larval supply (puerulus settlement) would be an improvement over just using the standardized commercial landings per trip.

Muller et al. (2000) used methods similar to those in Muller et al. (1997) but they incorporated two additional indices based on FWC's observer program: legal-sized lobsters and pre-recruit lobsters. They conducted sex specific analyses but combined the upper and lower Keys. Fishing mortality rates were lower than in any previous studies ranging from 0.49 per year to 0.30 per year with a natural mortality rate of 0.34 per year. The spawning potential ratios ranged from 24% to 29%. They also included a non-equilibrium surplus production model that used data from 1978-79 through 1999-00 that estimated very similar trend in biomass. They also included a retrospective that indicated that by including the pre-recruit index the very high recruitment estimates in the final year were eliminated.

The common finding in the previous assessments was high effort and no trend in recruitment.

8.0 Management Data Review

The participants discussed this performance measure twice. The general consensus was that the data sets are fairly extensive and robust. The participants recognized that no management changes are being proposed at this juncture, but could be suggested at later stages in the comprehensive review process.

9.0 Recommended Assessment Methods

The workshop participants expressed the desire for multiple assessments to be completed. The participants stated that the ability to compare across assessments would be particularly useful. As of the report submittal date, three assessment approaches are being developed. Two are not length/age based and one is the length/age-based assessment developed by the Florida Fish and Wildlife Conservation Commission. Finally, the participants recommended that this age-based assessment use three separate growth curves, tag-recapture curve, lipofuscin curve, and the Tortugas fishery curve.

Finally, for the age-based assessment, the participants decided to start the assessment in 1985, which at the time the best information flow began, especially trip tickets.

10.0 Research Recommendations

Research recommendations came out during the course of the discussions on each topic. They are listed below.

Work to develop an active program for a juvenile tuning index

Develop a greater understanding of the interaction between lobsters and traps

Develop research partnerships with the fishery

Try to reestablish an onboard fishing vessel monitoring program

Increase understanding of lobster disease

Continue to understand growth

Develop future assessments that take into account the role males play in determining fecundity.

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Appendix B – Notes from the Workshop

SEDAR Data Workshop Notes

Tuesday, January 25, 2005

Introduction, Housekeeping, and Participant Introductions

General Discussion of Stock Assessment-Putting the Data Workshop into Context

Bob Muller: Purpose of a stock assessment: Synthesize and integrate all available information, assess changes, assess stock condition, and compare with benchmarks to establish patterns of change.
Have we identified all sources of information available?
What is the quality of the information?
What information is missing and how can it be obtained?

Nelson: It's critical to calibrate the data.

Stu: The data workshop is a critical time in which to establish what data is available, if it's accurate. "The assessment is only as good as the data that goes into it."

Nelson: It's a necessary challenge to link ecosystem assessment with a stock assessment. "A stock assessment cannot be done in a vacuum."

Discussion and Decisions on the Terms of Reference

1. Determine the quality and appropriateness of life-history information.
Reproductive characteristics- *Mark* Evidence among decapods that availability of sperm is critical in reproductive studies. In addition to sex ratio, a m/f size
Stock Structure and unit stock id
Natural Mortality
Ageing methods, age structure sampling, and age determinations
Growth models, by length and weight

2. Determine the quality and appropriateness of stock abundance indices.
As written in Terms of Reference document

3. Determine the quality and appropriateness of fishery data.
Stu & others: Discard mortality is important point, survival of discards
Leave the "discard rates, release mortality, and estimated discard removals" as is or change to agreeable phraseology.
Mark: Trap related impacts on growth, mortality, and disease? Where in terms of reference does it go?
Skip: What is the extent of illegal/nonreported landings and where in assessment?
Unreported landings should not be termed "unreported"..makes it sound as if fish houses aren't reporting.

Doug G, Mark: Recreational discard info?
Nelson: for Terms of Ref wording… lethal vs nonlethal effects of discard…
Stu: **Leave wording as is, will be understood during discussion portion in document**.
Ralph: Discards: regulatory
Rick: Biological sampling details
4. Provide a review of past assessment methods.
John: Use it or cross it off?
Nelson: Should be done.
Bob M: Will handle this portion.
Stu: Important to compare old and new methods when assessment patterns change.

5. Determine the quality and appropriateness of available data for estimating impacts from proposed or existing management measures?
Nelson: Economic assessment? For example impacts of the trap reduction program?
Bob: What are the changes in the fishery and do we have the data to assess it? More short-term fishery changes are the point.
Nelson: Are we dealing with the resource or the fishery?
Ralph: Can biological data be used to examine fishery changes? ..management changes?
Simon: Leave wording as is, management procedures in place have large impact on stock
Gary: Do we have data that determines impacts of management (MPAs SPAs) on stock?
Doug: The purpose of this data workshop is biologically oriented …impacts on STOCK, not on society.
John: This wording in the terms of reference should be left in, but at this point will not be addressed in detail. At this point changes in management are not proposed..changes in season, size limit, bag limit..etc… but could be at later stages in the assessment process.

6. As is
7. As is
8. As is

Life History

Lyn & Rod **Life History of the Caribbean Spiny Lobster *Panulirus argus***

Habitat

Depth of adult lobster range is temperature and habitat dependent.
Is there agreement for the purposes of this stock assessment that it is extraordinarily unlikely/physiologically impossible for lobster to travel/swim back & forth to other areas of the Caribbean? Yup.

Feeding Habits

Feeding habits of phyllosoma larvae: *Skip:* Able to use leg to spear fish larvae (5x larger than themselves), transport it and feed off it.

Natural Mortality

Estimates are size, locale, and age related. 0.3-0.4 M = 23-25% annual mortality

This is an enormous data gap.
Continue discussion after life history section

Reproduction
Female reproductive size 70-75mm CL, though 50s mm CL have been observed w/eggs.
Mark: Sex from a Large Male's Perspective

Males are disproportionately affected in fisheries due to their growth size capabilities.
Relationship between size of spermatophore and #eggs.
The amount of sperm passed to the female has an enormous impact on #eggs & fertilization success.
Number of eggs produced is not controlled by the female, but by the amount of sperm available.
Larger males produce larger amounts of sperm and larger spermatophores; and can recharge more quickly than smaller sized males.
Behavioral compensation in heavily fished populations.

Rediscuss this issue at end of Life History

Male size at maturity and reproductive discussion**.** ***Bill:*** **Mean 98mm CL, but Mark's lab work, functional male maturity size is smaller 80 something mm CL.**
Tom: **It's possible maturity is age-related and not just size related.**
Ed Little: **Feasible to study male reproductive maturity…. find a source population in the Caribbean.**
Nelson:
Doug: **Internal vs external recruitment and reproduction. More conservative management approach regarding this issue.**
Research this issue & discuss at end of Life History.

Multiple clutches of eggs & how that plays into the assessment. Discuss at end of Life History.

Mark: Virus

Rod: **Further testing for viral transmission into other *juvenile* species is warranted.**
Virus data is a flat trend in the Florida Keys since 1999.
Is it already incorporated into M?

Growth and Age :

Bob Muller *Based by tagging- about 25,000 tagged with 6400 recaptured* not including *Looe Key Data.*

John Hunt What data is available that is not known? Adult tagging (fishery)
Bill Sharp 87-89 for Looe key
John Hunt Do we incorporate juveniles?
Bob Muller We would love to, micro wire tagging Forcucci 89-90
Mark 3 to 4 other data sets 1991-

Database that Bob is showing is incomplete due to lack of larger animals. Ran model out to 15 years.

Bob Females reach legal size at about 19-20 months where male may reach legal size at 15 months after settlement. This is fishery dependant data. Lobsters that were caught in traps and tagged could be size selectivity.

Stu May have truncated some of the older animals due to a longer molting time period of 3 months.

Hunt May have to have a graded scale where smaller animals have a shorter molting period and a longer molting for larger period.

Doug 74-75 data need to look at the comment section to see if pre or post molt.

Nelson Did not have very large males, use variation mathematics for size to estimate the parameters for intermolt period. Use data from other fisheries for other for very large males.

Data gap for Growth very large males and their intermolt period

Doug would it be worthwhile to tag in the Dry Tortugas.

Ed: Need 2 people to tag very large animals, NEEDS to be done!
Mark Can be done
Hunt Data set Bob is showing use data from different tag types.
Tony Need to research new tag types

Tom Matthews Talk

How do we incorporate non-molters?
Mark Growth increase variation is around the size that juveniles start to forage and leave algal phase and start crevice stage
Bill We have data sets on how tagging affects growth
Hunt In this talk we have juvenile data that is needed for bobs data sets
Mark We have this juvenile data also that we can pass onto Bob

Lipofuscin

Mark what accounts for the variance in the Lipo
Mark did you take a measurement of first walking leg to measure physiological age.
Nelson Should you change the axis in this graph?
Doug 20% of landings is reported from the keys so is the Tortugas fishery actually separate from the Keys Fishery?
Hunt there is possibly settlement in the Tortugas or lack of high quality settlement habitat
Rod settlement happens episodically in the Tortugas

Nelson is the pressure in the fishery for the Tortugas and the keys affect a differential mortality in each fishery.
Hunt Possible to use several different growth curves for stock assessment. Do we pick one or use a combination of all of them?
Mark A single factor possible for growth is density dependence
Bruce Keys is similar to Cuba data but asymptote faster
Tom Lobsters that enter the fishery may range in age from 8 months to 40 months
Hunt Where did we get the size distribution data?
Tom Size distribution was taken from observer data.

Data Gaps Regional fast and slow growing areas.

Mark Blood protein may be available for regional data

Roy Could the gaps be due to random or non-random assigning lipofuscin values to sizes?
Mark What ecological factors would drive male into cohorts and not female?
Mark Possible MPA slow growth may be due to density dependant

Can Tom growth curves be used for Stock Assessment?
Could have a major implication for the fishery

Mark Make sense if you use reproductive data from the Tortugas because the ones in the Tortugas are large "teenagers" but not reproductively active yet.

AFTER BREAK

Some decisions that are to be Made
Growth curves
Mortality rates

Morphometrics equations to be used. Done

Reproduction with males how to incorpoate them

Growth
Bob 1) Lipofuscin growth curve of the keys to be used plus 2.) tagging info and the 3) Tortugas because you are bracket it. How sensitive should the function be. We are trying to age the 70 to 100-size group. We can dump the larger animals into a single size category. Then M will be consistent with growth curve. Faster in one or on the other hand slower in the other.
Hunt Do we pre-assign L infinity, K, M
Bob We can convert all these into von Burtlanffy. Which M will we use with each curve.
Hunt The generation of these curves should be done during this workshop. Possiblely tonight.
Hunt Comfortable not to include the juvenile tagging data because it will not change that much

Mark Is the Tortugas really a different area ecologically?
Bob Tortugas is the fast growth and can be used
Mark should we use a different stock assessment for the Tortugas
Tony we should decide the Tortugas as a different Stock
Doug I think the Tortugas is the same stock but were able to escape.
Mark Not the population is different but the pop dynamics may be different
Doug sure it is different but is a continuum
Ed Look at Tortugas separately but also combine them as one stock
Hunt What happens if you take this suggestion and you do separate assessments
Bob Probably not able to do a separate assessment in the Tortugas, same animal and has been fished for 80 years and not virgin territory just less fishing pressure there
Mark Lobster fishery in the Tasmania fishery is the same scenario and they treat them with separate assessment but we know this is temp. driven.
Doug Density dependant the large animal dominance in reproduction
Skip Keys is intense fishery both recreational and commercially where the Tortugas is different in this aspect.
Nelson Conch example. M is different in Tortugas than here maybe because of an artifact.
Catch at age matrixes
Bob catch at age data sets but where do we put the Keys assessment Matrix with the keys data but not in the Dry Tortugas
Stu maybe we can use this as forth alternative using the Dry Tortugas may be good but may need more years of data with a suite of assumptions.
Lyn Different growth curves because of recreationally and commercially intensity
Bruce Can go to the same fishing area year after year it is the same size lobster but around the corner it is a smaller size but the same size year after year.

Hunt Summary
1. Generate matrixes with k, m, l for tomorrow using 3 methods coming up with equations
2. What about Tortugas using it as a 4th alternative and could lead to future directions

Internal vs. external recruitment and the council reviewed this and used the internal recruitment

What will we do for this assessment?

Nelson agrees but if spr is not small
Bob always local recruitment and spr is 18-22%
Eric(eggleston) agrees but stock/recruitment linkage does not exist it does not make sense
Bruce agrees aslong as spr is relatively large
Doug landings stable for 30 years and if assessment says other wise we need to redo

Growth – age/length keys

We will have One age/length key instead of an annual key?

Nelson agrees if we have a statement that explains the smoothing of the recruitment

Bob growth curve but there is variance
Hunt age/length key that can be discussed at the at the second meeting

Disease

Concerns may not be part of the assessment
Trend that is flat
Coincidence Maybe that 2001 and since had a lower than average landings
Nelson mentioned that the diseases may be already incorporated

Tony and friends already incorporated an M
Tom hard to ignore
Have not seen previous to 2001 incidence
Hunt disease is hitting juveniles prior to hitting fishery
Mark Experiments time involved in ifestions transmission
Roy Not affects adults and needs consideration because effects recruitment, along with sponge die off black water events
Hunt is there a tuning index in this Is it already included
Bob handle in different ways 1-year-old animals are effected and the varation in mortality assuming there was not trend, but has there been a trend since 1995. Who knows because who has studied 20-25 mm animals?

Mark *was there a change e in density of the small animals and has data back to 1988, Is there evidence that the disease affects the fishery*

Hunt it is premature to incorporate disease in this year's stock assessment and therefore is already incorporated in M with a star in the data gaps
Nelson that thought is supported with events in the Caribbean basin
Fishers agrees
Eric agrees
Tom M – disease may be ready at the end of this summer
Bruce – In M with a * but how much of a part does it play

Male Sperm Count

Bob what is the sex ratio and size in time only data back to 1985 maybe in early data sets. How much have the males been depleted but from what
Mark look over trends but not fDM
Bob shorten data set to 1997

Mark *if assume traps are fine but if there is a compensatory factor?*

Individual based model on Juveniles that can be put in an assessment context? This Year?

Bob gives you an understanding of individuals. But Stock assessment assess the populations but can complement each other.

Fecundity should it be incorporated

Bob needs another term called prob. of fertilization and assume you have not sperm limitation and the # of eggs reduce by the # of males.
Eric Just have to quantify it.
Tom over time there has not been a change in sex ratio
Hunt Worth playing with for discussion groups but not useful for the assessment
Nelson can create risk assessment
Mark nothing in the field data that suggest that there is a difference
Rod there is no difference between keys and Tortugas with male limitation.There is a difference and seeing a result of **an egg and a sperm and you lose egg production because you are only counting embryos**
Eric large broods and multiple broods
Bob yes
Hunt we are fine as is

Commercial Fishery
Trip interview Program (TIP)

Rick's talk

Josh Bennet a point of contact for the entire database
140,000 lobsters have been sized and sexed throughout the state
From Fisher Directly
Tortugas are multi-day trips
Marquesas is included in the Tortugas location
Tony Florida bay and Naples, Everglades, and over to Tortugas fishing occur we need to get fishing samples done
Rick there some people starting to sample these areas but still not much

Hunt how are these data used in assessment
Rick 140,00 lobsters length distribution more males to females ration, Do we want to use they data from outside the keys, as you go north lobster tend to get larger

Roy Limitation for standardized catch rate per week soak rate
Rick catch rate per trip is small
Nelson provides dynamics of what is happing in the fishery
Rick Fishers bring in traps prior to end of season and then are done
Tom Least productive traps come out early
Roy how often do they pull
Rick in beginning around a week but as seasons continues the soak time become longer

Hunt generic quality errors ie 500 traps = 527 and soak time of 1 week = 6 days to 9 days is this important to be acuate
Bob no because we are trying to determine short mortality, and the number may be rough but give you an estimate of an magnitude
Rick cooperation is good and agrees fisher and not grossly incorrect

Bob data collect not randomized is not ideal but will work and depicts how things really are
Roy Tip data collection not randomized has not posed previous problems
Jeff trip ticket info accurate is date, species, pounds, price/pound other info may not be accurate and is just filled in the blanks such as depth, area, soak time.
Jeff Phone interview may also may not be accurate info
Bruce face to Face (tip) may be more accurate than trip ticket
Ralph tip info may be only good as the interviewer.
Lyn does not believe quality of info has changed over time
Tom some change due automation in Tallahassee and improves
Hunt Tip and Trip ticket is used in assessment
Ed every Trip ticket is seen by him and there are some misgivings in the info
Doug Factors such as interviewer and interviewee or sex of either can affect the data collection
Doug if you do not stratify how do you know if it is representative?
Nelson how was the 2.5 % distributed with interviews compared to actually landings
Hunt regionally partitioned
Ed Ching Ping suggests that samples are not representative but if you randomize the samples you may miss opportunities. Suggest chase boats

Hunt *we are assuming that this is representative but not a statistically randomized method and overcome its shortcomings by a high number of samplings so these data will go into this assessment*

Wednesday January 26, 2005

8:15 am

comments? – doug is back!!

Growth wrap-up – Muller
Mark – l-infinity not realistic because the animals get much bigger in tortugas, we have growth increments for tort animals in the lab
Muller – agrees not realistic

Comments move to molt interval more important than increment
Tom – the molt increment is still big in large animals – *John* agrees
Muller – increment or interval – *Mark* interval should not change
Eric- heavy fishing pressure distorts because ethe fishery takes animals the would be there – living only the slower growth
Enheart – neede to se it in year one
Hunt - disagrees
Enrheart and Muller agree the tort curve should look different – *Muller* – we just don't have the data
Hunt – distorted mortality rate in muller curve – size structure of catch is much wider (80-150mm *Tom*) – *Enheart* age structure is the same likely …

Hunt – need another curve based on lipofuscin values which could be artificially high – *Enheart* – suggesting a hybrid with lipofuscin at lower ages - *Muller* – what do you change the slope too – *Tom* – yes we can change the curve but to what ??
Hunt – general discomfort in growth curve – audience agrees
Muller – if you assign an l-inf - .. it's not hard but if fishery modifies the growth curve, you need to go with it
Rick – divers get larger lobsters by 10 mm
Muller – we know that but there aren't that many to change that curve
Rick, divers work in an area where there are bigger lobsters
Tom – and the traps up there catch bigger lobsters too.
Com fisher – we get bigger lobsters there too.
Hunt – it's a small number of lobsters –
Moe – use the data that best represents the fishery -
Hunt – problem – we won't learn anything knew – get the same assessment. Lipofuscin and l-infinity changes the assessment
Doug – lipo concerns – it's too early to use it - depends on what they are eating – there are no gulf animals that are going to the Tortugas; wser lipofuscin data – want to see it – how does it compare to the fishery?
Hunt – WSER is tiny
Tom – fishery and wser is the same – no problem
Enheart – comment – why so high (reverse the axes), need to run a logistic
Hunt – Tom, reverse and do logistic …. To audience, this is an exploratory phase, don't worry about fishery management at this time
Tony – I'm fine – let's go with it – Graves buys lots of tort but the big ones are gone – tort is important
John – Tom revise the plots with Bob and Enheart, whatother data available ….

9:09am

Overview, landings, effort, gears, and discards – Muller
Commercial harvest talk
- discussion started by *Moe* on divers' percentage, *Muller and Hunt* explained the divers component
Harper – what is a trip in this exercise
Muller – chops this exercise at one-day trips
Hunt – look at this diver stuff in 5 year blocks, show unstandardized charts
Doug – could we look at older data, overfishing look *Muller* – we have the data, Hunt agrees
Mark – assumes traps are accurate reflection of the bottom, traps changed in the past too
Muller – we do see something like that with the divers, yes that blip on the bigger lobsters
Doug – they use larger traps in tort
Butler – behavior, one big one gets in excludes the other
Hunt – has the demitri paper, curves similar
Muller – minimum size larger, then but curve basically the same

Muller – where to start with data .. problems outlined with earlier data, changes in report etc
Hunt- can get size from independent sources as a proxy; rephase – what year to start the assessment
Eric – start date will vary depending on what type of assessment

Tom – cpue etc how to go into model, or two models (size and cpue model)
Muller – none, observer catch rate, diver catch rate, spa info, use independent data as much as possible m- to guard against bias; and bait problems for example
Muller – Eric – agree, trying to fit things that try and reflect the actual population
Enhart – good fit comes from indepenent data that fit the landings
Tony – divers and traps – do you have the shrimp data – lobsters caught in shrimp data
Hunt – they would not have been measured … - chopping at one day, is this important, what's the effect of this chop? Bias out the Tortugas?
Muller – 91% are one day, where do you cut it. Tortugas trips probably the multi but also pooled trips in this data
Enhaart – convert it to catch per day rather than catch per trip
Muller / day or use it as a covariate
Enhart - /day
Commercial – do three sections (1 day, 2-7) and anything over seven days … ie 60 day trips if for example shrimp boats
Muller – takes down the idea … Hunt agrees with the three sections, and show the non-standard graphs too
Hunt – general trend charts, commercial fishers will focus on smaller things, and details – do we need to clarify it
Bruce – how many others in chart below average – look at the 80's
Muller – points out the low data points
Hunt – this is pounds per trip, this is not total harvest, lag periods show up in this chart
Doug – fishers change instantly
Tom – you can move traps and change number you have in stock but can't go out and buy gear instantly

Further discussion of effort – Matthews

Stu – question soak time off tickets, compare to observer data, esp on annual basis
Tom – yes – much gear left in the water (40%) although the marathon group goes to stone crab in October
Com fisher – certificates to non-fishers – are they in this chart?
Hunt – those switched to spl – not included here
Tom – this graph is only those with landings, these disappeared this does not include the group with no landings
Hunt – how traps in the fishery moved from "poor" fishers to a good one – as to why pounds per trap increase is real but … traps moved to better fishers how did not realize an increase. So the trap "saw" the <u>increase</u> (*my interpretation – rod*).

Discussion about the effort and that traps in the water are doing work whether or not someone is out there. Management has not changed effort much.
Com fisher – people adjust business to management –
Tom – yes – you always find a way
Com fisher – need to but in time of year, traps , all of it
Tom and John and Muller – yes
Tony – what was number of certificate in 2003???
Hunt – going to get that information
Simon – I had a lot of certificates but did not use them
Tom – that would produce an error in this
Muller – just pushes down the curve
Tony – there are speculators in this, thinks they will be selling – one person with 11 thousand
Com fisher – yes, if no reduction they will be getting rid of their certificates.
Hunt – we could drop 80thou certificates and have not effect – it's latent effort
Com fisher – yes – all that would need to leave before you'll see and effect
Hunt – frames this discussion on certificate program, how to deal with it in stock assessment – Bob uses trips
Muller – uses several things –
Eric – lots of different things can be called effort
Muller – goes back to looking at fishery independent information, observer data (more controlled)
Doug – chooses not to use dependent data
Muller – use dependant as an out check
Doug – need to review independent stuff

Wednesday 1pm

John – next discussion will be DISCARD discussion
Only one info on is lobsters as live attractants (not bait)
Is the only discard we will discuss
List:
Bruce – end of season discards
John – unknown mort
Regulatory discards – females w/eggs
Shorts too short
Tom – under 50 mm or abundant (more shorts than needed for attractants)
Doug – Davis data on hand caught lobs – injury
Bob – nice to quantify this
Doug – must be internal reports
John – rec handling discards, no info on this
Rick – discards after end of season – every lobster – same as Bruce's comment
Anne – any estimate of ghost fishing mortality – lost traps
Tom – yes, number of trap est. from mail surveys
John – falls into discard mortality

Not dealing w/this in quantitative fashion
Rod – do lobsters go into other gear, nets, trawls, crab traps, casitas,
John – they are harvested, not discarded
Bruce – more vulnerable to predators
John – that handeling is same as rec. handling, just by commercial fishers
These are all areas we have poor ability to address
Doug – prioritize rel. importance of types of mortalities – so we can prioritize research efforts
John – yes, later

Bait discussion – Muller – from Observer program
John – change y axis of graph to be trap hauls, not deployed
Butler – est of mortality an over estimate? Because it is instantaneous mortality
John – this was air exposure mortality – initial mort due to air exp. Later mort related to confinement
Tom – uses the control, which weren't exposed to air
Mark –
Eric – mort isn't linear
Mark – exponential – little at first, more in a couple of weeks – don't linearize
Bob – is curvilinear
John – is going to get paper – bet we could use 4 week control mortality
Tom – really the same short is in the trap, little mort in August
Bob – aug and September is the big confinement time
Eric – how many are discarded, not used as bait
Tom – the discussion we just had on discards
Jeff – what is natural mortality?
Bruce – bait offshore traps with legals
Bob – these are included in data from Observer Program
Butler – is there no trap dynamic data?
Doug – we have these data – gave them to Muller
Muller – Doug's homework figure out escapement rate
Tony – video of trap escapement exist
John – we think some proportion are doomed, not all
John – 14 % instead of 26.3% - 1st rec. to do this adjustment
For earlier seasons, prior to live wells, calculate with 26.3% until mandatory regulation
Shows positive results of management
Tom – also have data on what we saw dead in traps – close to 1million
Then apply nat mort
Simon – Tortugas traps, cowhide, no bait
Butler – data gaps, look at blood protein not in traps vs trap caught animals, and diffs to nutritional condition
Tom – randomly sample lobs in traps and get curves
John – all good ideas to add to list and prioritized
Jeff – protects some? From being eaten by turtles?
Tom – if habitiat is limiting?
John – not in Fl Keys

- this level of detail, look at Bobs on monthly level, any other tweek is very small, esp when applied in august – large amt of work for little adjustments
Doug/Stu – do it and prove it is not a problem, and forget it from then on
Tom – use two totally independent measures, or tweek
John – can try to inc. escape rates, etc.
- can remove Tortugas traps – they have a zero short mort
- all of these serve to reduce the number by a "very small" amount

Muller – all this based on traps/trip
- Pounds (based on total landings) or traps per trip – which to use?\

John – trips, makes better sense – captures effort
Muller – is there a preferred number of bait
Bruce – 2 at least, 3 or 4 if I can
Muller – only data we have is from observer program –
Bruce – worried abt short mortality – this is critical – worried about perception of commission, who will be regulating the fishery
Muller – we want the accurate info too, we're stuck with the info we have
Tom – argues that Tortugas is already in there, we oversampled in 1995, if we take it out, it needs to get taken out of everywhere
Doug – observer coverage isn't representative of area – is a bias
It would be nice to use landings and observer data from same place and time
Rod – how oversampled?
Muller – data are separated only by Month, and Tort/Keys
John – synthesize w/o bias
- question? General approach of calculate short mortality – comfort.

Yes, consensus
Tony – for now
Doug – give tweaks, yes.
JHH – in between now and when we write up the report – time constraints – like to see if we can agree for data workshop report, do the big tweak – until live wells, use 26% w/statement that it is prob a little high. Starting with live wells, 14%, and I will get the real number. Rest for assessment workshop, escape rates, Tortugas, do each one and come back and see how much effect these things have? Process acceptable? Time frame?
Bruce – high?
JHH – yes, escape rate will lower rate,
Tom –go back in time 89/90 live wells
JHH – yes stock assessment 1978 start. Escape rates differential rate w/exposure comes out – there will be a lot of thinking about this, this is why we need the time.
Tom – in a million trap world, was that the number of bait?
Simon – why go back that far
Muller – that is when assessment will start
Gaitanis - traps that have never been fished, never a million traps fished?
Jhh – official number provided by industry 750 K traps - .15 1.2 million certs – 939K accepted, best we will ever do
Doug – big assumption may need more discussion, over estimate – too many shorts
JHH – how many recycled baits vs fresh bait
Eric – create a prob. by daily info, mort rate, etc. could make an estimate

Muller – yes, prob thing, throw the dice
Stu – 2 average mort est before/after live wells, sending this w/rec to tweek – yes do this Also, sensitivity analysis – missing so much info, keep it simple. Too many possibilities. Too complicated to get true estimate
JHH I agree.
Stu – bracket the estimates – don't have enough info
JHH – stu's work on tag/recapture work during 78/79 station 9 – resulted in much much higher mort rate w/different approach. We need to move on
Barring any major disagreement, reconnect on consensus – make major change re: livewells, then recommend tweeks for assessment later.
Tom – we have 2 methods – is written up, direct observation
Bruce – total bait number died, as traps reduced, number slowly come down? Total bait that died, as traps reduced didn't come down as much.
Doug – this is impt. Seem to remember question, are these baits put in or could have put in.
Tom – what fisher said he put in.
Gaitnis – trap deployment days? Flat line. Number of shorts in trap is germain – not what was put in.
JHH – yes, all these things germane, prob won't make much diff w/calculation.
Change – Observer talk before Rec talk

JHH – development of indicies, have pls , juvenile surveys, adult diving studies, lots of trap studies – I incorp. Indep studies to build a trap based index. Jeep in mind both issues.

Tom's Observer talk.

JHH – the end of the observer program creates a big data gap problem – how to do one less burdensome to industry and fwc staff.

JHH take number of discards from baiting – observed dead lobsters
Tom – extrapolated out to total number of traps in fishery – just over 1 million each season
JHH – removed nat mort?
Tom – used 0.3 - 1million reduced by 25% - ¾ mil less to fishery
JHH – using observations of lobsters dead in trap, made estimate
Jeff – pounds per trap seems high – legal catch rate
Tom – catch rate if trap had been in water every day of the year
Tom – dead lobsters last in trap for 3 days only
Bruce – what multiplier –
Tom – used multiplier to how many died that we didn't see
JHH – reminded that this is a bigger issue to you than to us
Want to give you some mgmt comfort, this isn't the same issue that it was in 1983, is still the cost of doing business, it is all out there – we're just trying to define it – not anticipating that this will need to mgmt issues
We have to move on.

Break

Bill Rec. Talk

JHH use this survey from 1993 on?
Bob – will compare 2 day to August commercial, and use August commercial to back calculate rec landings before our survey time
JHH – to create rec landings before we did our surveys
JHH – used mail survey approach for est rec landings, creel survey to compare catch w/commercial catch sizes, occasional phone surveys on non-respondants to ask for respondant bias, and there was none.
JHH any data gaps?
Rod – might want to look at, Ault had numbers on headboats going to banks – might be able to work that in. seems to be enough effort out there to drive male female difference to convergence.
Tom – no licences for people on headboats,

BNP- talk Hunt for Kellison

JHH – new dataset on there, plan to use this Bob?
Bob – this was the one other than the observer catch per effort to consider using. This also has some 0 catch rates – some unsuccessful trips. About 10%. Prob more reflective than data from only successful trips.
Harper – which year to start assessment, there is creel survey back to 1976 from BNP. Doug has these data. Also for 1992, they did sample the 4 day miniseason. Some of the data lost w/Andrew that summer, but first 2 days were entered, and Doug sent these to Kellison last week. 76-85, asked fishers how many lobsters they released? Think have the same biases with this data re: fishing party size b/c of small boats coming to docks – *JHH* – less of a bias b/c of less waterfront homeowners. Bias in BNP creel survey.
Muller – relative ups and downs be the same,
Roy – fyi 87-91 lower, 92 commission doubled bag limit outside of Monroe Co. July 1, 1992.
JHH – back to 6 in BNP in 2004.
Muller – Cool, I love regulatory changes.
JHH – people shifted behavior, didn't catch outside, and came back down here
Gaitanis – that was our perception

JHH – tuning index talk before or after other talks?
Muller – afterwards
JHH – what is a higher priority tomorrow am? Fishery indep datasets or trap stuff?
Muller – indep. Stuff
JHH switching agenda items – noone ready – going back to regular schedule

Doug Gregory – Trap Study talk early 70s
Muller – some of the recaptures were put back in traps?
Doug – yes
JHH – from abund and size str good in a tuning index
Muller – don't have much historical data

Doug – can use sentinal catch rates in comparison w/this data
JHH – where I'm heading w/trap presentations – may be able to make a tuning index from a combination of these data
Ask Doug, Stu, Lyn, Tom, to stay – given disp. Locations, short time period, different locations, is it worth the effort to put them together using abund and./or size str, into tuning index

Kerry – Historical DNR trap data from '78-79
Data remaining cant be used for abund – but maybe for size-str. Tagged data – complete dataset is lost

JHH – that was very good.
Are those differences small enough to use migration data subset as proxy for whole?
Eric – are there any differences in movement by size?
JHH – slide has 2 figs, one has all data, one just initial captures of lobsters that were returned
Eric – smaller lobsters more likely to be recaptured?
JHH – maybe a little bias, 1-1.5 mm
Muller – one dataset is a subset of the other
Muller – temporal size patterns are different – migratory vs total
I have a hard time saying that one is a random subset of the other
Butler – no error bars, and look at magnitude is small maybe not biol sig.
Moe – there is some overlap
Butler – doesn't think numbers will mean much at all
JHH – use these data as one of the data points
Kerry – cant do error bars, not in orig. data
Eric – ecol vs stat differences 2mm is not much difference
JHH – YES

Rick's Trap Presentation
Deep h2o traps
Looe key

Doug – Sentinal Fisher Program
JHH – try something and see if we can make a decision
Have a long series of trap surveys.
Are we missing any?
Nelsons was short term.
Can they be cobbled together to make a tuning index.
These independent data would be the ones for indices, not fishery dependent.
Is it worth it?

75-76 trap surveys, gulf and atlantic side for 1 year Aug 75-April 76
calculate abund from a trap and size str from a trap
78-79 DNR traps FL bay, looe, ocean and bayside – size str, sex ratio
April-April
April 87-March 89]Looe Key deep abundance and size str

Aug 93- Observer program
Sentinal fisher 98-2001 sambos, lower keys Oceanside –
Spillover from COP June 2003

Tom said we turned Oceanside middle and lower keys to one area b/c no differences in data
Weakness is can we use size str from traps for an index? Also taps have catchability biases, berried females etc.
Doug – don't find a solitary lobster as readily in diving surveys

JHH – right now we use from all of these datasets, we use the growth results in the tagging curve, beyond that, dougs data from 75-76, stuff Kerry reported on. Do you want us to use these data as a tuning index?

Muller – adding 3 points to the tuning index. What do you get from doing this?
/are the traps the same?

JHH/Tony/Doug – yes
Stu – catch rate data? Ok, after 2 days discussion, have a question abt cobbling them together. There seem to be differences in size freq, etc in different areas.
Bob – the are all Lower Keys. nothing upper keys?
JHH – is the job of the data workshop to make the data decisions
Stu – may throw some tuning indexes out later at assessment workshop
JHH – don t want to just create work
Moe – what is the alternative?
Doug – can we defer this discussion – too small to represent fishery – no gulf stuff. Go back to 74-75 observer data, and see if the trap studies are representative? Wouldn't expect much differences between studies in 70's

Butler – deep stuff – really not rep. Of a very wide habitat. Different enough it could be a problem
Stu- I agree. Atlantic and Gulf index.

JHH – will mull this over. Don't need to get together. Hard day. Start tomorrow at 8am w/fishery independent surveys.

THURSDAY 8 AM

Start with Fishery Independent data bases
JHH-Woo hoo marathon beat coral shores last night
Discuss trap issues and are the methods useful
Need to get back to terms of reference by the end of the day
First do fishery independent data sets, then do growth discussions- doug will be speaking on growth
Doug-summary of lobsters put in traps
Jhh-back to fishery Independent data bases

Sources for tuning indices. These data sets are critical to the assessment

Shelley- FWC Puerulus influx data base

Establish long term record of recruitment in the keys make predictions on harvest

Whitham collector
Ross whitham first did this up in north Florida-idea from blown over Australian pine then apply it to the keys
Stu- basically the same collector
Jhh- was there a change in the style collector?
Tom-collector is not a trap- collections probably depends on current
Stu-late 60's data research on collectors by sweat
Back to shelley
Our collection started in 1987
Bultler- collect on day 7- there is some variation in settlement, but day 7 captures the most, use days until metamorphose study to determine this
Shelley- day 7 maximize catch and minimize loss
Butler and jhh point out other studies identify locations
Butler- measure of postlarval supply- late 80 s did plankton collection for 3 years and correlations were quite strong bet collectors and what is in plankton, our current locations are representative of the rest of the keys
Jhh explains why big munson and long key were chosen
Doug- is the sampling on going?
Jhh- yes
Butler- relates our study back to w. Australia
Jhh- goal is try to predict harvest, mentions brown shrimp prediction models in NC, predictions are only good in appropriately regulated fishery
Back to shelley- prediction is not really the objective right now- tuning index for larvae abundance

Post talk comments
Jhh- check 93 data- does it include grassy key
Muller- I have edited version
Jhh- bob, how make change from weekly to monthly
Muller- just more samples, adjust for lunar day, looks at number per collector
Butler- they fall off, early (weekly) values are inflated
Muller- willing to make changes
Jhh- need an index that reflects what arrives during lunar month
Butler- can convert weekly settlement to monthly settlement

Butler- ODU juvenile survey

Data begins in 1988- pretty continuous data set
Laurencia drop in 97- probably doesn't correlate to 2001 drop,
Lyn- what about 98 drop?
Jhh- we need to correlate habitat dynamics with fishery dynamics

Fisherman ralph- how do you decide sites to use?
Butler- initially try to find representative sites, then from statistics- include all sorts of sites (very good to quite poor), some are fixed sites
Tom- pick sites similar to earlier studies
Ralph – use same sites to evaluate change and see trends for management
Butler- this is why we use fixed sites, need long term monitoring
Jhh- fixed sites are good, b/c then you know they are good sites
Butler-not as good to bounce around to sites, waste time on bad sites, need a lot more effort
Tom- rather than lobster count, need to look at index
Jhh- details- incorporate age of artificial shelter?
Butler- age of shelter is not specified in these graphs- maybe incorporate that later
Bruce- 97 drop in algae- did animals adapt to this drop?
Butler- no, if there is no habitat, animals are preyed upon
Jhh- very high mortality when clear out habitat
Butler- animals don't settle in the sea grass areas- not good habitat
Jhh- neither tagged animals nor new animals were found in cleared out area
Back to talk
juvenile abundance should be correlated to habitat coverage, sometimes true, sometimes not, because some places are habitat limited and others are not, but can you make predictions? Yes, both habitat and # of post larvae drive correlation

<u>post talk comments</u>
jhh-jhh argues for postlarval supply and butler argues for habitat as best predictor of juveniles- pretty difficult question, but both are important
bias of timed surveys- CARA surveys. We turn off clock when we capture, because it takes a while catch all members of a den. Maybe we should switch gears for this.
Butler- 60% of juveniles are in groups, but it is rare that there are big groups. Juvs don't take as long to catch, so the bias is not as strong for juveniles. Question- should we make this change (stop clocks)? or accept small amount of bias and keep the data consistent?
Mulller- need to track search time, catching is not as time consuming in juvs
Jhh- how important is a pattern verses the magnitude of the pattern, go back to highest density sites- when no clocks are stopped- big bias.
Muller- if this is a function of habitat, then just scale with habitat type if you can link habitat type with juv abundance, becomes nested
Doug- track trends over time, if saturated (huge amount of lobsters) get bigger bias
Muller- look at overall trend and make adjustments for habitat to see if it explains any variance, but hab data might handle this. Tie to 1 year animals. Whether you stop or continue the clocks probably doesn't make a big difference
Doug- there is a 30 minute diver saturation- can only catch so many lobsters in 30 min
Jhh- we need to do meta analysis on juv data on all past studies to look at usefulness of all this data, and look at the timed search bias. Not comfortable, knowing bias exists, wants to know magnitude of bias
Rod- 2 other things. Searches are only 10 minutes now rather than 30, and the animals are getting larger now- now there are adults in these locations.
Lyn- diver experience is also an issue, new divers take a lot longer catching lobsters
Jhh- similar to latent effort for trap fishery

Ralph- are the habitats ranked?
Jhh- yes we know the details of the structure- how many sponges, etc. now we need to analyze structure and invert abundance
Ralph- does site have numeric rating, to see if site improve or worsen, because 1 scientist says one thing, another disagrees and the fishermen say another thing. Fishermen were right- bay was dieing. Would be good to have scaled information on habitat
Butler- change in protocols, so last data point means nothing because it is 20 minutes instead of 60 minutes, need to be careful about making changes. When did this change happen?
Jhh- this is not a monitoring project, just a bunch of different studies- can we use them for assessment? To develop a juv index- we need a plan for future studies. Age of artificial habitats may be an issue. they probably change and over time become less attractive
Stu- experimental design issue are not the issue for this assessment, really, we need to know if the index we have is good or not
Doug- index should reflect changes, but has visibility been incorporated into the equation? Lots harder to find lobsters with bad vis
Butler- diver experience is definitely important, but each sample has a diver associated with it, and we know their experience, plus we didn't have inexperienced divers take these samples. If vis was really bad we didn't dive
Jhh- as far as using a juv index for this assessment this year- jhh thinks it is premature to develop the model yet- so we probably shouldn't use it yet. A recommendation from this workshop – is work on this to develop an index in the future and make it into a long term monitoring project, rather than a bunch of studies. Last few years have good data for this, but still premature

Lyn Cox- FWC Adult Monitoring using timed surveys

Timed surveys rather than transects surveys of adults on the reef, transects might result in a lot of 0's and less efficient use of time
Lyn needs to give butler Biscayne timed search surveys

Comments
Jhh- bob uses this data for one of his indices. These are various grants studies and they are all timed based surveys and are comparable
Lyn- visibility- number of lobster reflects the number the searcher sees not the effort of the searcher and the catcher. there may be some influence of visibility, but not much. Bigger issue is the experience of the searcher, but new divers were always trained as the catcher

Rod- FWC Adult monitoring using area based surveys

Jhh- Better to do timed or area survey? Tortugas cruise already had a protocol- an area based methodology, so we had to develop an area based survey

Rod talk- needed to increase the number of lobsters surveyed. There is no long term area based study, but several studies have been area based. How much area do you need to survey to get the sample number up? After some simulations, rod came up with 2000 sq meters
Jhh- adult monitoring. Issue is, we have both timed and area surveys, is there a way to connect the two surveys- a new index

Are these separately adequate for use?
What are thoughts for future, stick with timed, or switch to area surveys?
This summer we did both types of studies in the same area. Area first, then time survey, because time survey doesn't require catching animals= lots of disturbance
Bob has generated tuning based on time surveys, but he has never worked with area surveys
Tortugas surveys were designed as fish surveys which were area based surveys. Rod has tried to link the two types of surveys.
Rod- linking the two types of surveys is pretty complicated. Multiple aggregations are important and effect timed vs area surveys. Spree cruise detect differences bet different densities statistically. Area based surveys can give a good answer if do wide range of area, like looe key studies. Problem is that there is sometimes a huge den with a lot of lobsters= not evenly distributed
Looe key, part of forereef had a low contact, low disturbance. Count and leave lobsters, other studies, disturb them and collect extra data. Looe has both types of surveys
Lyn- in pilot study, keep time when doing area based surveys, also did this in Tortugas, so we do have a way to link the two methodologies
Jhh- efforts to compare to methodologies, they are sufficiently different and they might be to too difficult to combine
Doug- both are equally valid. Problem is sample size, uneven distribution so need big area to bring down variance. doug argues for traps to collect data
Muller- trap result in loss of habitat info, and visual info- muller has strong preference for non trap based index
Tom- size freq is different in traps than dive surveys
Doug- we need to design a long term effort to evaluate this
Eric- recommends a long term monitoring project that is very consistent.
tony- merits to traps, but other places you need eyes, fishermen should be a part of this data collection- can get much better data
doug- get away from the reserve, doesn't represent the whole pop
butler- diving and traps are sampling different areas. Traps are not right on reefs. A monitoring programs needs to take into account different habitat types- one or the other misses a lot
jhh- traps catch animals when they are foraging. Traps near reefs get same info as dives on reefs
doug -index is just an index. For the purpose of stock assessment, don't need sample number, just index
jhh- time based dives search enough area, sometime hit areas with no good habitat, so the sample is representative of the whole are. Area based dives- can do a bunch in a day and hit a bunch of different habitat- end result is same
doug -doesn't see big bias in traps considering the abundance of info you can get from it with relative ease
jhh- summary of biases associated with different methodology: bias of timed- small sample size. Bias of area survey- could have a lot of 0's- hard to see differences. Bias of traps- does trap really reflect abundance- and they select for certain sized animals, and if there is bait there is another bias by making it more attractive than adjacent hardbottom. Can't really do them all

tom- we do have trap vs dive comparison, in first year of WSER data there are high numbers from trap and low from diving= which means the end result was very different
jhh- based on rod's presentation on area based surveys, there is no index from this already completed- should we develop one?
Eric- lots of time gaps
Muller- no, don't use this data in stock assessment.
But- too new data, too biased an area sampled (lots of tort and looe)
Muller- how does it really relate to timed surveys
Eric- import data, but not for assessment

Eric Johnson- NC state mini-season dive surveys

Jhh- people may find this to be interesting data, and the question is-can this data be incorporated into area based surveys or a time index
Eric- probably not- too spotty and spaced in time
Not designed as a monitoring study 2000- 2005.- goal was look at distribution and abundance in great white heron wildlife refuge and key west national wildlife refuge
Looks at impact of 2 day mini season
Use both area based surveys and timed based surveys. Area by estimating distance from boat when finish dive
Huge declines in abundance in legal lobsters in both refuges after mini season
Muller- what does the sublegal abundance look like after season, that would show removal vs emigration
Gaitanis - you sampled the second time 3 weeks after mini season, not right after season?
Eric- yes returned late august
Jhh- be careful in evaluating that piece of the information. Similar numbers from older studies. Contents are most heavily fished in all of keys during mini season
Tom- very high diver densities
Jhh- dive in a group
Eric- count number of diver in boat to get diver effort
Butler- would be interesting to llok at animals in solutions holes, check out different habitiat
Jhh- maybe there is 50% removal from entire keys, what are the effects of this on the commercial fishery
Butler- if these numbers were true for all of keys, then there would be no commercial fishery
Jhh- hard to incorporate into existing indices
Lyn- has some extra data to tack onto this data
Butler- interesting to look at belts
Jhh- after lunch bob will talk about tuning indices, and we'll move onto to terms of ref etc
Lunch time

JHH – research needs
Develop tuning index monitoring – instead of cobbling like-minded projects together
Research needs can be e-mailed
4 wks to complete this
some things will change eg short mort. Estimate

Muller – Tuning Indices Talk

Could take out bait – and see if it makes a difference
Doug – assumes that bait pattern useage hasn't changed
Muller – really easy to address this
- big change I've seen is number of traps per trip post trap reduction
Doug – doing this by sex?
Muller – no, landing don't come in by sex – assessment isn't by sex
Hunt – bait in the pre=rectruit popn – so shouldn't they stay in
Muller – think we should subtract out bait
Hunt – this is an approximation –
Tom – we have confidence in the estimate, b/c what the fisher said they put in was what they put back in afterwards
Stu – used the shorts you had?
Bruce – yes
Stu – upped the number you put in based on what you catched – argues for leaving the number the way it is
Eric – one thing to look at – don't see it making a lot of difference
Muller – put it in, if it makes a difference, adjust it out – same as month, season, etc
Hunt – issue, if it makes a difference
Muller –change a signal of up and down
JHH – potentially changes an index that makes sense and works well, and make it the opposite
Eric – pull out evertything that is not abundance in popn
JHH – stu just said that # shorts put in trap is aspect of abundance in popn
Havent convinced me that it doesn't reduce quality of index w/them out
Stu – what year? Gets really convoluted
Muller – put it in, see if makes a diff, then look at shape of pattern – peel off layers of onion – hadn't thought abt bait – and when they start – seems to me if cowhide is different than 1 short, then we look at that and account for that
Stu – can try a lot of things – recordimpacts in results of this workshop so assessment panel can evaluate based on our arguments –
Muller – have to take out years w/12 bag limit…
JHH another way to deal w it – take a look at catch rates, go back in a less derived portion of data, by group size
Muller – number of divers
JHH – not just divers, 88 yr old grandma get part of bag limit
Harper – database contains number of fishermen in party,
JHH as long as number of people in boat – not those that get in h20
Muller – number of times # lobsters per person exceeds 6
JHH – didn't increase their catch ouside of Keys, just perception they could catch more
Checking through different sources to see if reg changes made a difference in behavior – if not, can keep those years in
Rod – mail survey data, Dade – very slight increase, but not limiting
Muller – when were changes exactly – will get off of computer
Tom – for weekly data, lower b/c not collecting all month
Butler – use Total?
Muller – yes
JHH – how many late pulls?

Muller – check see what the longer pulls were?
Doug – random wont matter
Muller – checks 5s vs 5s
Tom – it absolutely matters – bob's way is lower – sums would be higher
JHH – good news, more years of data, early years mean less and less
Mark – to me, look at odu relative to this, same general pattern – early ODU only 4 year overlap – before that are entirely different – suggests not to worry about these details
Eric – think you are set up
Stu – remove the overlap so we have 2 completely independent measures
Butler – check and see what you are calling ODU data.
We will get muller some more data – ESB etc – Looe
Eric – how do you feel abt this being representative of whole fishery –
Muller – is rep of lower keys, where is a big part of the fishery
Tom – use sublegals or legals?
Muller – get applied to different parts of the data
JHH – homework give you the additional data
Doug – suggest taking reserve data out – reserve is increasing while non-reserve is going out – reserve isn't rep of the fishery
JHH – trap based indices – we can use COP, looe key, Oceanside 75-76, do we add them?
Stu – no, except COP
Muller – dougs non-reserve and cop non-reserve
Lyn – give him the data`
Jhh – do we delete the data off the ftp site that we aren't going to use?
Muller – no
JHH – thought we weren't going to do juv index for this stock assessment
We can revisit this.
Butler – if all you are looking for is a standardized number of juves, not to hard to create – I was thinking you wanted a predictive thing which would take to long. The first is easy enough task. We can do it.
Muller – would really like the habitat index, but wouldn't be ready for this assessment.
Tom – would have to be standardized to be really useful.
JHH – no juv index in this assessment at all.
Muller – ok, pls will play that role.
JHH – these lines and figs are how the data from all these presentations have been applied as inputs to the stock assessment –
Have rejected the datasets that would be inappropriate – and will get more data to expand tuning indices
Muller – size drives the assessment – have info from rel number sizes by year, have diff fisheries, trying to work at the population end of this not the fishery end
Trying to explain patterns – bring in other info, but also catch and size is bulk. If decision to make curve fit, uses the indices. Trying to give the program a reality check – not mathematically, but reality.
Eric – can be run w/o the tuning indices. Use these to make it better
JHH – long term adult/juv monitoring prog based upon natural habitat, do we use traps, cinderblocks, all we're really doing making tuning index as goal – but purpose is nothing

more than to "keep the computer honest". Work needs to be commensurate w/mission. Only one is pl monitoring since it became monthly.
Juvenile stuff is in research mode.
Concensus confort on tuning indices
Bruce – size from all data ?
Muller – from Rick and fish houses – what portion the fishery is impacting. Those numbers are used to scale the numbers in the popn. Catch used to tie to it. Calc size of popn, observed size of that portion of popn, match them up. Tuning to improve the outcomes.
JHH – is why long term databases are good to have. Can rethink using the juv index – limitations because is not designed to do this. Will reask the question? Stick the juv 25-45 index back in.
Butler – biases, recent changes in protocol (dive length)
Lots of different divers –
Sites weren't randomly chosen – could standardize by habitat/shelter density
That isn't that hard to do, could do it.
Muller – super
Butler – limit it to just season
Muller – no, leave it in an use month
JHH – lets move along. Juv index back in? Yes or no?
Moe – how accurate
JHH – yes or no
Bruce – leave it up to the guys who know better than we do
Gaitanis – the more the better
Doug – we have plenty of indexes, but if you want to use it, do it.
JHH – what we don't have is a longterm index – all others are short term
This one goes back to mid-80's
Doug – no objection
Mark – gut feeling, not many ways to fuck this up. As long as good spatial representation
JHH – yes or no
Stu – the more indices we can trust, the more you put in, the stronger the assessment in the long run. Impt worth trying to put it in.
Muller – put the beast in
Gaitanis – fall into the category of best available data?
Eric – attractive, because it is long term
JHH – what I'm hearing is yes, stick it in. we need to spend some time to talk abt trap/juv/dive monitoring for the purpose of generating tuning indices, and come up w/a plan. Down the road. So we're done this am session. Now to homework assignments.
Growth terrifies me.
Muller – don't go near it
JHH – doug…
Doug – **UF 75 Tag Recapture Project**
Stats folks used data to estimate escape rate (back in the day), t bar tagging method
Turn the data over to Bob to work with
Tom - Any exposure time?
Doug – Only trap to trap
JHH – What's the outcome? What will you do with the data?

Lyn – Recommend add the COP data to this.
- John chastises Ralph for giving "me these looks"…again
Muller - Other homework outside of growth to answer JHH question
Seasonal catch rates for divers based on "learning curve"?
Conclusion: Catch rates almost double in early season between 92-97 and 99-03 due to large casita use
Question 2, Why do I standardize rather than just report pounds per trip?
Muller demonstrates difference b/t non and standardized lbs per trip….difference between relates to several factors changing over time…trap numbers etc…
Doug – Where data come from?
Muller – Trip tickets
Bruce – Revisits latent effort conversation and how selling out of traps effects individual effort changes not so much, but overall effort into the fishery much more
Stu – Effort…Max stays high for trap #s, but now the avg. is approaching that max
Muller – What they're doing now is different than what they used to do.
Bruce – I pulled a thousand before the hurricanes (one day).
All – ooh aaah wow daaaaang that's a LOT
Ralph – What is that per minute?
Doug – Why would you not want to use this an an index?
Muller – You're gonna love this one… I prefer to use fishery independent data …complexities of trap info, I don't have as much faith in records and data (especially that info known only by the captain) that's why the trip info is so important. If I had thousands of trip info (interviews) it would be great… but that's not the case
JHH – Limitation of TIP?
Muller – Really limitation of personnel available to conduct interviews. NRC recommends not using fishery dependent data.
JHH – Growth…Dealing with that just overnight is producing results that clearly cannot be resolved overnight. Bob & Tom will work it out.
Three growth curves. Assessment of full fishery using each of the three and Stu's recommendation using Tortugas separately. So, we're at the same point of discussion and will need to address that later.
Decision needs to be made…what year to start the assessment?
Muller – We have the ability to start with length info 78, 1985 or so Ed Little's work, 7 years of missing size data, Trip info starts in 85, do we start w/ later work?
Butler – Other data sets start later. More in line with one another.
JHH – Ok. So that's how it'll be. Later …starting 1985 or so. Ok, on to

Terms of Reference

1. Determine….life history.

JHH, Muller, Stu – It appears to be covered and has been adequately covered w/ earlier notes and with tape.

2. Determine…..stock abundance indices.

JHH, Muller – The last hour, did that, covered that

3. Determine ….fishery data.

JHH – Covered with dataset talks, etc..

Cox – Don't recall discussion that was suggested earlier about unreported/illegal landings
JHH – Within the framework of this stock assessment, anyone have a sense of increase?
Bruce – Yes, definitely, a lot of it heads up to Miami.
Cox – Have arrests increased?
Doug – Depends on the time frame and when/what you're talking about.
JHH – Unreported and illegal has gone up, but short issues have gone down due to enforcement/penalty issues.
Muller – Acknowledge that this issue exists, but there isn't a way to assess it for the stock assessment.
Stopher – Does any short information exist for the Rec fishery in the mail survey?
JHH – Not short, but exceeding bag limits. This is already in the data, though.
Tom – Observer program has some data, but does not reflect "robbing rate".
Jeff – What about Marine Patrol/Law Enforcement reports of incidents?
Stu – It appears that illegal landings get reported somewhere.
Skip – Illegal traps, too,
Bruce – But those animals will end up being reported, it's just the trap that's illegal.

4. That's Bob's.

5. JHH – This one is still sort of a mish mash for me, but I think the data is ok.
Cox – From my notes, we were going to discuss management changes and if the data answers the questions
Stu – That's for the managers really, and it's more of a question if the data can answer any questions they may bring up.
6. JHH – That is a term of reference, and we have not done that.
Butler – there are really only two people in this room that can do that.
JHH – and Nelson as well, recommend do that by email.

7. JHH – We have done a lot of that, Tom also mentioned prioritization of that. Not sure can get my head around that right now.
Tony – Future reference- We can take from this meeting to the industry that it is imperative to work together from the BEGINNING and go from there.
JHH – I agree in concept and we use "industry" in …will never get total "buy in" on that… Email me with research ideas, doesn't have to be a science proposal. It'll be compiled with those we've already heard and will probably not be prioritized but will be there for use.

8. JHH - Gonna do that.

March 15-17 Assessment Workshop
We're gonna need more stock assessment scientists there.
Doug – We should try to get the BOCC room for better room and circular for better communication.
JHH – Doug, will you do that?
Doug – yes
Rick – What about Audio/Vis at BOCC?
Doug – They won't do it unless we're a political group.

JHH – Need to try to keep it in Marathon. Anyone with any last comments.
Muller – Thank you to the industry folks for attending.
Stu – Second that.
Tony – Thank YOU for including us.
Xoxoxoxooxox Room full'a love.
Tony – Thank you John, who did a bang up job and keeping it on track.
JHH – It's been interesting and difficult, but have learned a lot. Thank everyone for participation.
WE'RE DONE.

SEDAR 8

Stock Assessment Report III

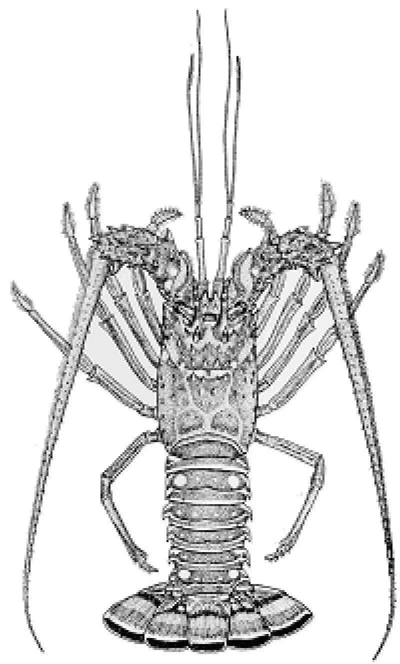
Southeastern US Spiny Lobster

SECTION III. Assessment Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

SEDAR 08

Southeast Data, Assessment, and Review



Assessment of spiny lobster, *Panulirus argus*, in the Southeast United States

Stock Assessment Report

Prepared by

SEDAR 08 U.S. Stock Assessment Panel

29 April 2005

1.0 Introduction

The Florida Fish and Wildlife Conservation Commission (FWC) is the primary manager of spiny lobsters in the State of Florida. The key biological management measures are a minimum size (3 inches carapace length or 76.2 mm), closed season during the bulk of the reproductive season (April – August), a prohibition on the taking of egg-bearing females, and various measures designed to reduce discard mortality (use of live wells on vessels transporting sub-legal lobsters; prohibition of spearing, etc). The commercial fishery is regulated through an effort management program designed to control and reduce the total number of traps used in the fishery. Trap numbers have declined from more than 900,000 just prior to the implementation of this program in 1993 to slightly fewer than 500,000 today. However, a commercial dive fishery has flourished in recent years and the recreational fishery remains large. Allocations between these sectors have shifted in recent years prompting a constant tweaking of the state's management plan. In response, the Commission directed staff to conduct a three-year comprehensive review of the fishery from both an assessment and management perspective. Any and all management options could be considered during this process. One decision was to place our assessment into the SEDAR process to bring in new data where available, to bring in the active partnership with stakeholders in the assessment process, and possibly to build new assessments into the overall evaluation of the fishery. Once this is complete, the Commission will use the outcome from the assessment to reevaluate all aspects of the management plan in partnership with stakeholders.

1.1 Workshop Time and Place

The Stock Assessment Workshop was held in Marathon, Florida at the Marathon Garden Club and the Florida Fish and Wildlife Conservation Commission - South Florida Regional Laboratory from March 15 -17, 2005.

1.2 Terms of Reference

1. Identify appropriate modeling approaches based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.
2. Document any deviations from Data Workshop recommendations or modifications to data provided by the Data Workshop.
3. Estimate stock parameters, including but not necessarily limited to the following:
    - Population abundance at age
    - Population biomass
    - Spawning stock biomass
    - Fishery selectivity at age and size
    - Fishing mortality

Yield
Stock-recruitment relationship

4. Evaluate uncertainty related to input data, modeling approach, and model configuration. Provide representative measures of precision for stock parameter estimates.
5. Provide complete SFA benchmarks. Evaluate any existing SFA benchmarks, estimate alternative SFA benchmarks if appropriate, estimate SFA benchmarks (MSY, Fmsy, Bmsy, MSST, and MFMT) if not previously estimated.
6. Evaluate stock status relative to SFA criteria. Provide clear statements of stock status relative to 'overfishing' and 'overfished'.
7. Estimate ABC and TAC levels, if appropriate.
8. Evaluate the impacts of current management actions, with emphasis on determining progress toward stated management goals.
9. Provide recommendations for future research and data collection (field and assessment); be as specific as possible in describing sampling design and sampling intensity.
10. Provide an Assessment Workshop Report based on the SEDAR Assessment Report Outline and addressing the Terms of Reference.

1.3 List of Participants

Beaver, Rick
Boragine, Ralph
Braynard, Shelli
Cox, Carrollyn
Cramer, Jeff
Cufone, Marianne
Gaitanis, Robert
Gaitanis, Tom
Gregory, Doug
Hunt, John
Iarocci, Tony
Idoine, Josef
Jackson, Anne
Johnson, Eric
Kellison, Todd
Kennedy, Stu
Lessard, Karl
Mahmoudi, Behzad
Matthews, Tom
Maxwell, Kerry
Moe, Martin
Muller, Robert
Murphy, Michael
Powers, Joseph
Sharp, Bill
Slade, Stopher
Williams, Roy

(See Appendix A for contact information)

2. Data Issues and Deviations from Data Workshop Recommendations

The primary data issues that were not brought to the Data Workshop were the catch-at-length matrices by gear, sex, and fishing year and the corresponding catch-at-age matrices (Tables 2.1, 2.2). The catches-at-length were developed by calculating raising factors (Gulland 1969) with landings and length frequencies from the Trip Interview Program, Biscayne National Park's creel survey, FWC's observer program, and FWC's creel survey. The length frequencies were matched with landings by gear, region, fishing year, season (Jul-Oct, Nov-Jan, and Feb-Mar). For the purposes of matching lengths to landings, we used six regions: Northeast (North Carolina to St. Lucie county Florida), Southeast (Martin-Dade counties), the Upper Keys (Dade-Monroe county line to Marathon Key), Lower Keys (Marathon to Marquesas), Tortugas (West of the Marquesas), West Coast (Collier county to Texas) (Fig. 2). In the summaries, we combined the three Florida Keys' regions. More than 85% of the landings had direct matches with lengths. Most of those landings strata without matching lengths were from either regions other than the Florida Keys or from gears other than traps. Filling in of lengths for those landings strata without lengths was accomplished by substituting lengths from other seasons and, for those landings still without matches, we combined lengths across fishing years.

Age-length keys for spiny lobsters were constructed from growth curves that were developed from tagging and lipofuscin information that was presented at the Data Workshop (Sections 2.2.2, 2.2.3). A difficulty with estimating growth in spiny lobsters is that lobsters lack structures that record age in a manner similar to otoliths in bony fishes. Therefore, a total mortality rate has to be assumed before one can create an age-length key from a growth curve. We used trial total mortality values of 0.34, 0.70, 1.00, and 1.30 per year to generate age-length keys that were applied to the catches-at-age. Tagging age-length keys by sex were constructed by applying a total mortality value to monthly growth trajectories of 1000 lobsters and the lipofuscin age-length keys were developed from Monte Carlo simulations of 1000 lobsters using the von Bertalanffy parameters and their standard errors by sex and the two locations. Thus for each carapace-length category, we determined the proportion of ages by sex. We fit an age-structured model, Integrated Catch-at-Age (ICA) discussed in Section 3.3.2, to each of the four resulting catches-at-age. The best fit, as judged by ranking the mean squares of the catches-at-age and the tuning indices, was with a total mortality value of 1.0. Although the catches-at-age fit better (lower mean squares) with lower total mortality values, the total mortality of 1.0 per year still had the lowest rank even when catches-at-age were included in the ranking.

Other data issues stemmed from recommendations at the Stock Assessment Workshop (SAW). For example, some of the tuning indices were recalculated because either earlier data were made available as in the case of the Biscayne National Park creel survey or the criteria for selecting the data to be included were revised. The puerulus index was recalculated after removing collectors other than those from the Big Munson site. Another example involved recalculating the two pre-recruitment indices using a wider length range of sub-legal lobsters because, when multiple molts were considered, spiny lobster down to 47 mm carapace length (CL) could molt into the fishery during the year.

The procedure for estimating the sizes of spiny lobsters that could molt into the legal size class during a year was first to calculate the mean growth increment per molt and the standard deviation of growth by 1.0 mm carapace lengths from tag-recapture data over the range of potentially recruiting lobsters -- 47 mm to 75 mm CL (Table 2.3(1), J. Idoine pers. comm.) There were few tag recaptures of lobsters that were smaller than 47 mm CL when they were tagged. The next step was, given the mean and standard deviation of growth increments, to calculate the cumulative probability distribution of growth increments for each carapace length and delete the top and bottom 2.5%; thus, identifying the range of increments within 95% probabilities (0 to 15 mm). We next got the probability of each increment by carapace length by subtracting the cumulative probability of the next smaller increment from the cumulative probability of the increment of interest. The length x increment transition matrix was composed of these probabilities normalized to sum to 1.0 across increments for each carapace length. The probability of molting for each carapace length was estimated from the equation given in the Data Workshop Report, Section 2.2.2:

$$P = \frac{e^{(1.233-1.458\,Season+0.538\,Sex-0.0643\,CL+0.0696\,Days\_free)}}{(1+e^{(1.233-1.458\,Season+0.538\,Sex-0.0643\,CL+0.0696\,Days\_free)})}$$

where season was summer or winter, an equal number of males and females, and 60 days free (two month) and the number of molts per year was six times the two-month probability. The proportion of lobsters by size from 47 mm CL to 75 mm CL came from either the observer program or the adult monitoring program depending on the index. Sizes of lobsters were grouped by their number of molts; for example, the sizes 47 and 48 mm CL could molt five times in a year and so we multiplied the number of pre-recruit lobsters by the transition matrix five times. After each molt, we tallied those lobsters that had attained legal size, checked the number of lobsters to ensure that none had been missed, and then let the remaining pre-recruits molt again. The result was that an average of 99.3% of these pre-recruits attained legal size within a year. Therefore, the pre-recruit catch-rates were recalculated using lobsters with carapace lengths of 47-75 mm. To corroborate this modeling exercise, we extracted all lobsters less than legal size from the tagging data that were free more than 180 days and were recaptured at a size larger than at tagging. Twenty-two of the 28 sub-legal lobsters were recaptured at legal sizes. The smallest lobster was tagged at 46 mm CL and recaptured at 76 mm CL, 288 days later, and there were two 51 mm CL lobsters, one was recaptured after 288 days with a carapace length of 79 mm CL and other lobster was 94 mm CL after 318 days. The values of the tuning indices that were used in subsequent analyses are shown in Table 2.3(2).

3. Stock Assessment Models and Results

A variety of assessment models were presented at the Stock Assessment workshop ranging from models with minimal data requirements such as the non-equilibrium surplus production model (ASPIC, Prager 1994, 2004) and a modified DeLury model (Rosenburg et al 1990) to several age-structured models including untuned Virtual Population Analyses (VPA), tuned VPAs (FADAPT 3, Restrepo 1996), Integrated Catch-at-Age (Patterson 1998), and ASAP (Legault and Restrepo 1998). The rationale was to see whether different analyses produced similar results.

3.1 Non-equilibrium surplus production model.

3.1.1 Non-equilibrium surplus production methods.

3.1.1.1 Overview

Surplus production models were among the earliest fishery models because they required minimal data: landings and effort. Initially these models assumed equilibrium conditions (Scheafer 1954) but recently fishery scientists have relaxed the equilibrium assumption in these models (Hilborn and Walters 1992, Prager 1994). Prager's implementation (ASPIC) allows the use of tuning indices in addition to the landings and effort data.

3.1.1.2 Data Sources

We developed the model using landings data from the 1978-79 through 2003-04 fishing years. Commercial landings were combined across gears and the recreational landings were extended back to the 1978-79 fishing year through the use of regional regressions of recreational landings in biomass on the August commercial landings. The regressions of recreational landings from the mail survey for the Northeast region and the West Coast were not significant (Northeast F = 0.95, df = 1,10, P = 0.95; West Coast F = 1.49, df = 1,10, P = 0.25) and so we used the 1992-2003 average landings for the earlier periods in those regions. In the other regions, the regressions were significant (Southeast F = 7.03, df = 1,10, P = 0.024; Keys F = 21.8, df = 1,10, $P < 0.001$) but the intercepts were not significantly different from zero so we recalculated the slopes without intercepts. Special Recreational Crawfish license holders (SRL) are required to report the number of lobsters that they caught to FWC three times during the fishing year (Data Workshop 3.2.3). The SRL began in 1994-95 but before this license was created most of these individuals had Saltwater Products Licenses (the commercial license) so that they could exceed the recreational bag limit but the SRL holders did not sell their catches so their harvests before 1994 were not reported. As with the recreational landings from the mail survey, most of the SRL trips were made in August and so we used the August commercial landings to extend the SRL landings back to 1978-79 fishing year. The landings by sector are shown in Table 3.1.1.2. We used the standardized commercial catch rates (Data Workshop, Figure 3.1.1 (5)) and the Biscayne National Park creel survey catch rates (Table 3.1.1.2) calculated as kilograms per trip using the weight per trip based on the survey's carapace lengths converted with the length-weight equations in the Data Workshop's Table 2.1.7(1).

3.1.1.3 Model Configuration and Equations

There are two simple equations for the surplus production model, the first equation relates the biomass at time $t + 1$ as a function of the biomass at time t:

$$B_{t+1} = B_t + rB_t(1 - \frac{B_t}{K}) - C_t \qquad (1)$$

where B_t is the biomass at time t, r is a net rate of growth in biomass, K is the carrying capacity of the environment, C_t is the catch during time t (Hilborn and Walters 1992). The second equation relates the catch to the biomass:

$$C_t = q\, E_t\, B_t \qquad (2)$$

where q is the catchability coefficient which links either effort, E_t, to biomass. There is another catchability coefficient linking the tuning index, q_{BNP} to biomass. Thus, the model reduces to solving for a biomass to start the series, B_1, and r, K, q_{land}, and q_{BNP} by minimizing the differences between the observed and predicted catches by sector.

3.1.1.4 Parameters Estimated

We used logistic option in ASPIC version 5.05 (Prager 1994, 2004) which solves for B_1 / K, K, q_{land}, q_{BNP} , and maximum sustainable yield (MSY) instead of r. The model starts with initial values for these terms and then searches alternative values of these parameters to identify the set that minimizes the objective function. Once the final values have been identified, then the benchmarks can be calculated. The logistic model gives the biomass at MSY, B_{msy}, as $K/2$, and the fishing mortality rate that produces MSY, Fmsy, as MSY/B_{msy}. Prager points out that ratios of F/Fmsy and B/Bmsy are more robust than the actual values of the individual terms.

3.1.1.5 Uncertainty and Measures of Precision

ASPIC evaluates uncertainty empirically by re-running the analyses 1000 times with bootstrapped residuals. The uncertainty in F/Fmsy can be tallied to indicate how many of the outcomes were less than 1.0 and similarly, the uncertainty in B/Bmsy also can be tallied to indicate how many outcomes were above either the maximum stock size threshold (0.5 or 0.66) or 1.0 indicating that the biomass was at or above Bmsy.

3.1.2 Non-equilibrium surplus production results

Most of the runs with ASPIC did not achieve solutions without having at least one parameter reach a limit. The typical solution put the carrying capacity at its upper limit and the corresponding catchability coefficients were at their lower limits. The SAW thought that the fishing mortalities of less than 0.05 per year were unrealistic. We also tried combining the sectors into a single catch time series and did find one combination of starting values that produced reasonable results but were unable to get the same results after changing the random number seed. The difficulty in achieving a clear robust solution reflects the lack of contrast in the data (Figure 3.1.2). The AW members decided not to consider this model any further in this assessment.

3.2 Modified DeLury model.

3.2.1 Modified DeLury methods.

3.2.1.1 Overview

The Modified DeLury model (Rosenberg *et al*. 1990, Basson et al. 1996) is similar to a surplus production model except that the units are in numbers of lobsters instead of biomass and the population only increases by recruitment. The Modfied DeLury was promoted at the FAO Caribbean spiny lobster workshops in 1997 and 1998 in the Western Atlantic (Restrepo 2001) and recently has been used for Florida pompano (Muller et al. 2002) and spiny lobster in Cuba (González-Yáñez et al. In Review). The model estimated population sizes and fishing mortality rates of the recreational and commercial sectors and for the bait used in traps by fishing year.

3.2.1.2 Data Sources

As with the surplus production model, we used commercial and recreational landings and effort. However because the DeLury model uses the landings expressed in numbers of fish, we had to convert the commercial landings in biomass to numbers using the catches-at-length by fishing year and gear. The recreational landings in biomass were extended back to the 1978-79 fishing year for the surplus production model (Table 3.1.1.2) and these were converted to numbers by the 1992-2003 average weights. The same process was applied to the SRL landings.

The numbers of lobsters that were used as bait were summarized in the Data Workshop Table 3.1.2 (1). The estimated bait usage in numbers was extended back to the 1978-79 season in two steps. First we estimated the monthly number of trap hauls combining monthly trap landings, the monthly landings per trap from those trip tickets that included the number of traps, and the average soak time by month with trips tickets that were available back to July 1985. We then applied the monthly average number of sub-legal sized lobsters per trap hauled from the 1992-2003 observer data to the estimated monthly trap hauls. The bait mortality rate was 26% per four weeks of confinement in traps (Hunt et al. 1986) prior to July 1987 when the live-well requirement was implemented and 10% per four weeks afterwards (J. Hunt personal communication). Since almost all of the commercial landings prior to the 1985-86 came from traps, we extended these estimates back to 1978-79 by regressing monthly trap hauls on landings which allowed us to calculate the trap hauls by month for the earlier period and to which we applied the same monthly average number of sub-legal and legal sized lobster per trap haul and the 26% mortality rate. The landings and effort data are shown in Table 3.2.1.2.

All of this extrapolating might seem like a lot of work for nothing but actually this exercise accounts levels of removals from the population that otherwise would not have been included in the assessment. The objective function excluded the extrapolated values.

Data Workshop members identified six tuning indices for the stock assessment: the number of legal-sized (CL > 76.2 mm) lobsters per trap from FWC's Observer program, the number of pre-recruit sized (47-75 mm CL) lobsters from the Observer program, the number of legal-sized (CL > 76.2 mm) lobsters per trap from FWC's Adult Monitoring program, the number of pre-recruit sized (47-75 mm CL) lobsters from FWC's Adult Monitoring program, the number of lobsters per recreational trip in Biscayne National Park, and the number of pueruli per collector (Data Workshop Section 6.0). Three indices of the indices were revised after discussions at the SAW: the two pre-recruit-sized lobster indices and the puerulus index. A SAW panel member suggested using molting and the resulting carapace lengths as an objective way of the identifying the size range to include in a pre-recruit index. Based on the number of molts and the mean increment size by carapace length, the pre-recruit indices were recalculated with a range 47-75 mm of carapace lengths instead of 68-75 mm. Participants who were familiar with the puerulus collection program noted that the increase in recent years in the puerulus index came after the addition of the Long Key site and recommended using only the data from Big Munson Key in the puerulus index. The six final tuning indices are shown in Table 2.3.

The Data Workshop concluded that the natural mortality rate for Florida should be between 0.3 and 0.4 per year (DW Section 2.1.3). After extensive discussions on natural mortality at the FAO Spiny Lobster Workshop in Belize in 1997, the FAO participants chose 0.34 per year. In these analyses, we also used 0.34 per year for natural mortality.

3.2.1.3 Model Configuration and Equations

In this DeLury model, the number of fish at time *t+1* (N_{t+1}) is:

$$N_{t+1} = N_t \exp(-Z_t) + R_t \qquad (1)$$

where Z_t is the total instantaneous mortality rate during time t ($Z_t = F_t + M_t$) and R_t is the recruitment at the beginning of time t. Because many spiny lobsters molt into legal sizes during the closed season, we have recruitment occurring at the beginning of the fishing year. The predicted catch for a given sector is:

$$C_{s,t} = q_s E_{s,t} \overline{N_t} \qquad (2)$$

where $C_{s,t}$ is the catch during time, t, from sector s; q_s is the catchability coefficient that relates the mortality expended by one unit of effort in sector s; $E_{s,t}$ is the effort expended by sector, s, during time, t; and $\overline{N_t}$ is the average number in the population during time, t. $\overline{N_t}$ is :

$$\overline{N_t} = \frac{N_t}{Z_t}(1 - \exp(-Z_t)) . \qquad (3)$$

To prevent the model from attempting to use negative recruitment values, Carl Walters recommended having the model solve for relative recruitment anomalies (Ra_t) that are scaled by the recruitment in the first fishing year (R_1). The equation is:

$$R_t = R_1 \exp(Ra_t - 1) \qquad (4)$$

and R_1 is approximated by the number of lobsters dying during the first fishing year ($N_1(1\text{-}\exp(\text{-}Z_1))$).

Predicted index values, $\hat{I}$, for the legal-sized population were fit to the average population size during a fishing year:

$$\hat{I}_{j,t} = q_j \overline{N}_t \qquad (5)$$

where j refers to the index. These indices of legal-sized lobsters were the observer catch per trap from 1993-04 to 2000-01 and the FWC adult monitoring number of lobsters per dive from 1997-98 to 2003-04. The predicted index values for the number of lobsters per trip from Biscayne National Park's creel survey were fit to the beginning population size because the creel survey was conducted in late July:

$$\hat{I}_{j,t} = q_j N_t . \qquad (6)$$

We used three indices to tune recruitment: the puerulus index offset two years, the pre-recruit index from the observer program, and the pre-recruit index from FWC's adult monitoring program. The predicted recruitment index values were calculated from:

$$\hat{I}_{j,t} = q_j R_t \qquad (7)$$

where *j* refers to the index and t refers to the fishing year. We calculated correlation coefficients between the log-transformed observed and predicted values and included only those parameters in the final model that were significant at the 0.05 level.

The objective function was the sum of the lognormal likelihood terms for the landings by sector, the tuning indices, and the recruitment anomalies (Hilborn and Mangel 1997). The log-likelihood (*LL*) for each component was:

$$LL_j = n(\ln(\sigma) + \frac{1}{2}\ln(2\Pi)) + \frac{1}{2\sigma^2}\sum_{i=1}^{n}(\ln(I_{j,i}) - \ln(\hat{I}_{j,i}))^2 \qquad (8)$$

where σ^2 is the variance of the log transformed values of the index or landings by fishery sector and these values were input to the model, *n* is the number of observations, $I_{j,i}$, is either the sector landings or index, *j*, and *i* refers to the fishing year. In the case of the recruitment anomalies, σ^2 was set to 0.25 and the sum of squares, SS, portion of equation (8) was

$$SS = \sum_{i=1}^{19}(Ra_i - 1)^2 \ . \qquad (9).$$

3.2.1.4 Parameters Estimated

The model, developed in Excel, uses the Excel Add-in Solver to identify the initial number lobsters in the population, N_1, the catchability coefficients by sector or tuning index, and the number of recruits entering the fishery each year. Therefore, in this configuration, the model solves for a potential total of 36 parameters: N_1 (1 parameter); the recreational, commercial, bait usage catchability coefficients (3 parameters); coefficients for each of the six tuning indices (6 parameters); and the recruitment anomalies by fishing year (26 parameters). Indices that were not significant were excluded from the objective function in the final run and so that run had only 33 parameters.

3.2.1.5 Uncertainty and Measures of Precision

We evaluated uncertainty with the modified DeLury model with likelihood profiles for the initial population size, the fishing mortality rate in the final year, and biomass in the final year (beginning population number times average weight), and re-running the model with alternative natural mortality rates of 0.25 and 0.40 per year. We developed the likelihood profile for the initial population size by solving the model over a range of initial population values (5 to 30 million lobsters). The likelihood profile for the fishing mortality rate in 2003-04 was developed over a range fishing mortality rates of 0.20 to 2.70 per year after setting the initial population size to the most likely value and forcing the model to match the specific fishing mortality rate by assigning a large penalty (1 million) to the difference between the fishing mortality rate in the final year and the set value. The likelihood profile for the biomass in the final year was calculated in a manner similar that for the fishing mortality rate. The biomass was varied from 1750 mt to 14250 mt. To simplify the results, we plotted relative likelihoods which were the likelihood values divided by the maximum likelihood value. The Stock Assessment Workshop members recommended running the model with two alternate natural mortality rates, 0.25 per year and 0.40 per year as sensitivity runs.

3.2.2 Modified DeLury Results

3.2.2.1. Measures of Overall Model Fit

The fit of the DeLury model to the data was evaluated by calculating correlation coefficients of the log-transformed observed and predicted harvests and indices and excluding the components with probabilities of the null hypothesis that were greater than 0.05 (Fig. 3.2.2.1, Table 3.2.2.1). Neither of the observer indices nor the FWC adult monitoring index of legal-sized lobsters was significant and so the final model was re-run without these indices.

3.2.2.2. Parameter estimates

In the final run of the DeLury model, the initial population size (1978-79) was 12.5 million lobsters and the number at the beginning of the 2003-04 fishing year was estimated at 10.4 million lobsters with a biomass of 5750 mt.

3.2.2.3. Stock Abundance and Recruitment

The number of spiny lobsters and the recruitment by fishing year is shown in Figure 3.2.2.3. The number of lobsters was bimodal -- one peak in 1979-80 and a second peak in 1999-00. The marked decline in 1998-99 fishing year was consistent with low catch rates in August 1998 but was confounded by the scattering of traps and disruption of the fishery by Hurricane Georges in September 1998. The general decline after the 1999-00 fishing year is a concern because it is too soon to tell if the decline is similar to the earlier decline following the 1979-80 fishing year and will begin to increase. Recruitment did not help us answer this question because recruits comprise a large portion of the lobsters available to the fishery and so the pattern of recruitment mirrored that of abundance. On a positive note, fishers at the SAW said that the current fishing year, 2004-05, was a very good year.

3.2.2.4. Stock Biomass (total and spawning stock)

The DeLury model does not distinguish between spawning lobsters and non-spawning. Biomass was estimated as the number of lobsters at the beginning of the fishing year times the average weight in that fishing year and so showed a pattern (Fig. 3.2.2.4) similar to the plot for numbers (Fig. 3.2.2.3a.

3.2.2.5. Fishery Selectivity

Selectivity is not applicable in the DeLury model because the model is not age-structured and only estimates a single population value per year.

3.2.2.6. Fishing Mortality

Fishing mortality rates across gears have been variable over this period (Table 3.2.2.6, Fig. 3.2.2.6). After 1986-87, fishing mortality rates increased to a peak in the 1991-92 fishing year, the impacts of Hurricane Andrew on infrastructure in August 1992 lowered fishing mortality that year and then the Trap Reduction Program was implemented in July 1993 such that fishing mortality rates were generally declining after the 1991-92 fishing year. Initial catch rates in the 1998-99 were sluggish as evidenced by the drop in recreational fishing mortality rates and then Hurricane Georges in September 1998 disrupted the fishery by scattering traps. The fishing mortality rate in 2003-04 fishing year was 0.85 per year (recreational F was 0.20 per year, the commercial F was 0.60 per year and the bait mortality was 0.05 per year).

3.2.2.7. Stock-Recruitment Parameters

The scatter in the Stock-Recruit plot precludes identifying a unique curve (Figure 3.2.2.7(1)). The poor relationship between biomass and the resulting recruitment in Caribbean spiny lobster was expected because spiny lobsters have an extensive (six to nine months or longer) planktonic phase prior to settlement. Lyons et al. (1981) argued that the low variability in recruitment in Florida suggested that recruitment here was supplemented from sources outside of Florida. Spiny lobsters occur in many areas of the Caribbean and currents flow from the Caribbean Sea through the Yucatan Straits and form either the Loop Current going into the Gulf of Mexico or the Florida Current (Fig.3.2.2.7(2). The Loop current eventually recombines with the Florida Current to form the Gulf Stream. Morrison and Smith (1990) monitoring current flow in the Caribbean Sea observed a transport maximum in the eastern Caribbean (Aves Ridge) and detected a transport maximum in the Florida Straits approximately 90-100 days later. Florida's downstream location means that Florida could receive recruits from the Caribbean, Mexico, Cuba, or local production. Silberman et al. (1994) collected a total of 259 lobsters from nine areas extending from Antigua and Martinique in the eastern Caribbean to Florida and Bermuda. They used mtDNA to examine genetic diversity and found 187 unique haplotypes and of those haplotypes, 168 were unique to single lobsters. They concluded that *P. argus* is a single genetic stock shared by many countries. Sarver et al. (2000) found two specimens of the Brazilian sub-species of spiny lobster off Miami, Florida.

3.2.2.8. Measures of Parameter Uncertainty

As mentioned in Section 3.2.1.5, uncertainty was examined by developing likelihood profiles of the initial number, the fishing mortality rate in 2003-04 and the biomass in 2003-04. The likelihood profile for the initial number of spiny lobsters in July 1978 indicated that there was very low likelihood that the number of lobsters was less than five million; however, while the maximum likelihood was at 12.5 million, the likelihood declined slowly at higher initial numbers (Fig. 3.2.2.8a). The likelihood profile for the fishing mortality rate in 2003-04 had a defined peak at 0.90 per year (the point estimate was 0.85 per year) (Fig. 3.2.2.8b). However, the likelihood values for the biomass in 2003-04 were more variable and much lower than those for the other two parameters and for the most part they tended to be associated with fishing mortality rates near 0.75-0.90 per year (Figure 3.2.2.8c). The relative likelihood was at or above 0.99 from 5500 mt to 8250 mt. A possible explanation for the low values and ragged appearance is that forcing the model to achieve particular biomass values in the final fishing year while not allowing the initial population size to vary results in more variable solutions.

3.2.2.9. Retrospective and Sensitivity Analyses

Retrospective analyses of population numbers, recruitment, and fishing mortality rates were conducted by running the DeLury model with terminal fishing years of 1997-98 through 2002-03 (Fig. 3.2.2.9) using the same indices as in the final run even though their time series were shortened. We compared the results beginning with 1997-98 with those of 2003-04 using the average percent difference between the runs. The populations estimated in 2003-04 were, on average, 3% lower when they were the terminal year. The recruitment estimates in 2003-04 were on average the same as the earlier estimates, and the fishing mortality rates were 5% higher in 2003-04. However, two-tailed, paired-t tests showed that none of these differences were significantly different from zero.

The Stock Assessment Workshop members recommended running the model with two alternate natural mortality rates, 0.25 per year and 0.40 per year as sensitivity runs. As expected, the population and recruitment estimates were higher as the natural mortality rate was increased and the fishing mortality rates were lower. The total mortality values for any fishing year were similar with the largest difference being 0.08 per year against an average magnitude of 1.55 per fishing year (Table 3.2.2.9).

3.3 Age-structured models

Growth in spiny lobsters was estimated from two sources: tag returns and lipofuscin concentrations. The lipofuscin technique has potential to provide ages but in this case the aging was based on 51 laboratory-raised spiny lobsters that spanned only four years. To increase its utility, we need to identify the sources of variability in lipofuscin concentrations with the sex and habitat of spiny lobsters. For example, female lobsters had lower lipofuscin concentrations than did males of the same age and animals from the Dry Tortugas had lower concentrations than did lobsters from the Florida Keys. We ran the age-structured models with catches-at-age developed using both sources but chose to use the ages based on tagging for the base run.

The SAW looked at the results of a suite of age-structured methods ranging from catch curves (Robson and Chapman 1961), untuned Virtual Population Analyses, tuned VPA models (FADAPT3, Restrepo 1996) to statistical catch-at-age models including Integrated Catch-at-Age (Patterson 1998) and Age Structured Assessment Program (ASAP, Legault and Restrepo 1998). Carl Walters had his class at the University of British Columbia develop a Stock Reduction Analysis (SRA) for spiny lobster that began in 1897. FADAPT was not chosen because of its underlying assumption that the catches were known without error. Most of the runs with ASAP estimated large population sizes and fishing mortality rates less than 0.1 per year plus the mixture of weighting values and penalties made it difficult to choose the weighting values objectively. The SRA provided a historical context for examining this fishery; however, by necessity it required a stock-recruit relationship, as was discussed in Section 3.2.2.7, and we are unable to define the geographic limits of the spawning stock. Therefore, the SAW panel members decided to use the Integrated Catch-at-Age model.

3.3.1. Integrated Catch-at-Age

3.3.1.1. Integrated Catch-at-Age Overview

Integrated Catch-at-Age (ICA) is a statistical catch-at-age model that solves for the numbers at age in the most recent age, in this case 2003-04 fishing year, the numbers in the oldest age before the plus group, the age-specific selectivities, and the catchability coefficients for the tuning indices. The program has been evaluated and meets ICES's Quality Control specifications and is available from ICES. The two things make this model different from other statistical catch-at-age models are that the model runs backward from the oldest ages in the most recent years instead of solving for recruitment directly and the model allows for the selectivities to be applied only to a portion of the catch history. As a result ICA is a hybrid between statistical catch-at-age models and tuned VPA models such as ADAPT. Instead of assuming that the selectivity has been constant over the entire time period, we chose the years after the Trap Reduction Program was implemented to estimate the age-specific selectivities. The model solves for the numbers and fishing mortality rates for the earlier fishing years in a manner similar to ADAPT using the information from the 1993-94 fishing year as the starting point for those earlier years.

3.3.1.2. Data Sources

As noted in the Data Workshop Sections 2.2.2 and 2.2.3, growth was estimated from tagging studies and from the relationship of lipofuscin concentrations to known ages of laboratory raised spiny lobsters. Integrated Catch-at-Age used a single, combined gears catch-at-age matrix based on tagging in the base run (Table 3.3.1.2(1)), average weights at age and fishing year in the harvest that came from the catches-at-length (Table 3.3.1.2(2)), average weight at age and fishing year in the population that we approximated with the diver-caught lobsters (Table 3.3.1.2(3)). All lobsters that were 12 and older were combined into a single group (age-12+). The program allows for natural mortality rates by age and year although, due to lack of specific information, we used 0.34 per year for all ages and fishing years. The maturity schedule by age was approximated as 0.0 at age-1, 0.5 at age-2, 0.75 at age-3, and 1.0 for ages 4+ (J. Hunt, personal communication). The spiny lobster fishery begins in late July with the recreational two-day Sport Season and ends on March 31 of the following year; therefore, all of the fishing occurs before the spawning season (spring and summer with the peak in late May in the Florida Keys (Bertelsen and Matthews 2001)) while only eight months of natural mortality have occurred before the spawning season. In addition to the fishery data, we used the same six tuning indices that were used in the DeLury model: observer pre-recruit (Age-2) and legal-sized (Age-3 and older) numbers per trap, FWC Adult Monitoring pre-recruit (Age-2) and legal-sized (Age-3 and older) numbers per dive, the number puerulus per collector offset one year and applied to Age-1, and the number of lobsters per trip from Biscayne National Park's creel survey (Age-2 and older).

3.3.1.3. Model Configuration and Equations

Integrated Catch-at-Age uses a backward projection instead of the more familiar forward projection method; thus, ICA solves for the population numbers in the most recent fishing year (2003-04) and the number of age-11 lobsters which together with the selectivity and annual fishing mortality rates allows the calculation of the numbers of lobsters by age and year and the corresponding predicted catch-at-age.

In a separable model, the fishing mortality on any age and year, $F_{a,y}$, is:

$$F_{a,y} = Sel_a F\_full_y \quad (1)$$

where Sel_a is the selectivity for a given age, a, and F_full_y is the fishing mortality on fully recruited ages for given fishing year, y. The number of lobsters at age and year, $N_{a,y}$, is solved backward from the most recent year using the fishing mortality by age and year, $F_{a,y}$, and the natural mortality rate, $M_{a,y}$, from

$$N_{a-1,y-1} = N_{a,y} \exp(F_{a-1,y-1} + M_{a-1,y-1}) \quad (2)$$

and the average population during the fishing year , $\overline{N_{a,y}}$, is given by

$$\overline{N_{a,y}} = \frac{N_{a,y}}{(F_{a,y} + M_{a,y})}(1 - \exp(-F_{a,y} - M_{a,y})) . \qquad (3)$$

Therefore, the predicted catch-at-age, $\hat{C}_{a,y}$, is

$$\hat{C}_{a,y} = F_{a,y}\overline{N_{a,y}} . \qquad (4)$$

Predicted index values are calculated from the estimated number of lobsters of the appropriate ages and the catchability coefficient, q_j. For an aged index, I_j, the number of lobsters at age is summed across the ages that the index applies to and the catchability, q_j, or

$$\hat{I}_{a,y,j} = q_j \sum_a N_{a,y} \exp(Fraction_j(-F_{a,y} - M_{a,y})) \qquad (5)$$

where $Fraction_j$ accounts when the survey is conducted during the fishing year.

The objective function minimized the differences between the observed and predicted catches-at-age and between the observed and predicted indices. Assuming that the errors in the catch-at-age and in the indices were distributed lognormally, the objective function, *SS*, was

$$SS = \sum_a \sum_y \lambda_{a,y} \ln(\frac{C_{a,y}}{(\hat{C}_{a,y}})^2 + \sum_a \sum_y \sum_j \lambda_j \ln(\frac{I_{a,y,j}}{\hat{I}_{a,y,j}})^2 \qquad (6)$$

where the first term minimizes the differences between the catches at age and year and $\lambda_{a,y}$ is the age-year weight. The second term in equation (6) minimizes the differences between the indices based on numbers and the appropriate ages and λ_j is the weight given to index, I_j. In the case of spiny lobsters, all of the components were weighted equally at 1.0.

3.3.1.4. Parameters Estimated

Given the inputs, the model solved for 47 parameters including the fishing mortality rates on reference age-3 (the earliest age believed to be fully recruited) for 1993-94 through 2003-04 (11 parameters), the selectivities by age for this same period (9 parameters, the reference age of age-3 was fixed as 1.0 and the selectivity in the last age before the plus group (1.0) was specified during the run), the 2003-04 population size in numbers (11 parameters), the number of lobsters at age-11 for the other fishing years in the constant selectivity period (10 parameters), and the catchability coefficients for each of the tuning indices (6 parameters).

3.3.1.5. Uncertainty and Measures of Precision

This model evaluated uncertainty through a Monte Carlo process using 1000 reruns of the model with random draws for the parameters from the covariance matrix. From the 1000 solutions, we developed box-and-whisker plots of spawning biomass, recruitment and fishing mortality rates by fishing year.

3.3.2. Integrated Catch-at-age Results

3.3.2.1. Measures of Overall Model Fit

The measures of fit for ICA are the fit to the catches-at-age (Fig. 3.3.2.1 (1)) and the fits to the tuning indices (Fig. 3.3.2.1 (2)). An analysis of variance table with the sources, sum of the squared residuals, numbers of data points, degrees of freedom, and the mean squares is included as Table 3.3.2.1). All of the components were significant in this model.

3.3.2.2. Parameter estimates

For each of the 47 parameters that ICA solved for, the program presents the maximum likelihood value, the coefficient of variation, the 95% confidence interval, and the mean estimate. The parameters are listed in Table 3.3.2.2. As expected the CV values are higher in the recent fishing years and in the population estimates.

3.3.2.3. Stock Abundance and Recruitment

The estimated number of lobsters by fishing year varied from 30.4 million in 1985-86 to 39.3 million in 1999-00 and the estimate for 2003-04 was intermediate at 35.2 million lobsters (Fig. 3.3.2.3a). The estimated numbers of spiny lobsters by fishing year and age are included in Table 3.3.2.3. Recruitment expressed as age-1 lobsters was bimodal with an early increase in 1987-88 (17.7 million) and then a decline and another increase in 1996-97 (18.9 million) through 1998-99 then dropped reaching a low in 2000-01 (13.1 million) and then a gradual increase afterward with 15.8 million in 2003-04 (Fig. 3.3.2.3b).

3.3.2.4. Stock Biomass (total and spawning stock)

Total biomass generally has been increasing over the time series (t test for slope = 0, t = 2.40, df = 17, P = 0.028; Fig. 3.3.2.4a) albeit with fluctuations. The total biomass ranged from 15,000 mt in 1985-86 to 20,200 mt in 1995-96 and was 19,200 mt at the beginning of 2003-04. Spawning biomass also has been increasing (t test for slope = 0, t = 7.51, df = 17, P < 0.001). Spawning biomass has increased from 3,300 mt in 1985-86 to 5,700 mt in 2003-04 (Fig. 3.3.2.4b). Note that the small error bars in the years prior to 1993-94 reflect that the covariance matrix was determined only for the fishing years 1993-94 and later and the decreasing variability in the early years illustrates that VPAs converge.

3.3.2.5. Fishery Selectivity

Selectivity in spiny lobsters is dome-shaped with fewer age-1 lobsters available to the fishery, many of which were used for bait, lobsters became fully available at age-3 and then fewer at older ages (Fig. 3.3.2.5). A possible explanation for the decreasing availability of older lobsters could be movement away from the areas where the fishery is concentrated.

3.3.2.6. Fishing Mortality

Fishing mortality rates on age-3 (fully recruited) by fishing year have been variable but without trend prior to 2001-02 (t test for slope = 0, t = -0.54, df = 13, P = 0.60) and then the rates declined (Table 3.3.2.6, Fig. 3.3.2.6a). ICA also calculates the average fishing mortality rate of selected ages, in this case, we chose ages 1 through 5. The pattern of the average fishing mortality rates is similar to that on the fully recruited but lower because of the dome-shaped selectivity (Fig. 3.3.2.6b).

3.3.2.7. Stock-Recruitment Parameters

As noted in Section 3.2.2.7, recruitment in the southeast United States can come from spiny lobsters spawning in areas outside of Florida as well as the local spawning stock. FWC is currently developing a microsatellite DNA study of pueruli and adult lobsters from animals that are to be collected from several Caribbean locations in addition from Florida to address the question of recruitment origins. Given the possible pan-Caribbean nature of recruitment, we would not expect to see a tight relationship between the spawning biomass and subsequent recruitment (Fig. 3.3.2.7). To account for the age at settlement in the stock-recruit plot, we plotted the stock versus the number of age-1 lobsters offset by two years instead of one year. This is the same offset that we used in the DeLury model. The issue is not whether we can identify a unique curve but rather defining the spawning biomass that contributes to the spiny lobster populations in the Southeast U. S.; we know that the spawning biomass is greater than what occurs in Florida but we have no idea how much greater.

3.3.2.8. Measures of Parameter Uncertainty

Measures of parameter uncertainty were shown in Table 3.3.2.2 that includes the maximum likelihood estimate, the coefficient of variation, the 95% confidence interval, and the mean estimate. However, see the following retrospective section below for uncertainty that exceeds these usual measures of precision.

3.3.2.9. Retrospective and Sensitivity Analyses

Retrospective analyses were conducted over a range of terminal fishing years (1997-98 to 2002-03) by starting with the final run configuration of ICA and sequentially removing the terminal year's data from the catch-at-age and tuning indices. The retrospective analyses indicate that the model underestimates fishing mortality (Fig. 3.3.2.9(1)). For example running the model with the data through 2001-02, the fishing mortality rate in 2001-02 was estimated at 0.21 per year but when the 2001-02 fishing mortality rate was estimated using data through 2003-04, the value was 0.33 per year (54% higher) and when we average the differences across the retrospective runs then fishing mortality rates were on average 37% lower. If we look at the precision of the 2001-02 fishing mortality rate estimate in Table 3.3.2.2, the 95% confidence interval of the 0.33 per year extends from 0.26 to 0.42 per year and does not include the original estimate of 0.21 per year. Recruitment was overestimated by an average of 14% and the spawning biomass was overestimated by an average of 29%. As with the DeLury model, we tested the siginificance of these differences with two-tailed, paired t-tests and all of the differences were significant at α=0.05. Mohn (1999) noted that the retrospective bias stems from the changing catchability coefficients. Of the four tuning indices that were used in the retrospective runs back to 1997, three (Biscayne National Park, Observer pre-recruits, and puerulus) had significant positive trends. What this means from an assessment point of view is that the fishing mortality rates in the more recent years from this assessment are biased low and are expected to be higher in future assessments.

Sensitivity runs included runs with higher and lower natural mortality rates yielded predictable results (Table 3.3.2.9). Additional sensitivity runs included repeating the entire analyses with the two lipofuscin based age-length keys. Because the growth was faster than the tag-based age-length keys, we had to adjust the natural mortality rates in the lipofuscin runs. We used 0.50 per year with the Florida Keys lipofuscin ages (oldest ages used in the analyses were 9+) and 0.75 per year with the Dry Tortugas based ages (oldest ages used in the analyses were 6+). These ages represent the 99.5 percentile in the catches-at-age. With the faster growth using the lipofuscin aging, the fishing mortality rates were higher but when the rates were scaled to their means, the patterns with the three different aging methods were similar (Fig. 3.3.2.9 (2)).

4. Models Comparison

4.1. Compare and Contrast Models Considered

The non-equilibrium, surplus production model was unstable and was discard early on. The two models used in this assessment used the same landings converted to numbers and the same tuning indices. Differences between the models were that the DeLury model used fishery effort in addition to the tuning indices while the age-structured model, ICA, used the numbers of lobsters by age and fishing year to gain additional insights into the stock dynamics. Both models showed little trend in fishing mortality rates until the decline in 2001-02. The fishing mortality rates in the DeLury were higher than those estimated from ICA; however, one of the Stock Assessment Workshop members pointed out that the lower rates from ICA probably reflected the dome-shaped selectivity curve (Fig. 3.3.2.5) used in that age-structured model. The dome-shaped selectivity curve reduced the number of lobsters available to the fishery while the DeLury model assumed that the harvests were comprised of homogeneous lobsters that are all equally available to fishers. To test that idea, we divided the population estimates from ICA for the 2000-01 through 2003-04 fishing years and for ages four through ten by their selectivity. The adjusted population numbers were higher by an average of 39%. The DeLury model was then solved such that the ratio between the observed values and the predicted values of the legal-sized lobsters tuning indices was 1.39. The fishing mortality rates from the adjusted DeLury model were very similar (Fig. 4.1). The DeLury model did not have significant retrospective bias.

4.2. Preferred Model Recommendation

We are probably showing a modeling bias, but we are still going to use the age-structured model as our base model because we can include the length information under the guise of age-structure, maturity and spawning data. The DeLury model was developed more for oversight of lobster dynamics and the age-structured model for the specifics.

5. Population Modeling

5.1. Yield per Recruit Models

5.1.1. Methods

We calculated the yield-per-recruit empirically with the natural mortality rate of 0.34 per year across ages, the selectivity from the ICA model, the average weight by age using the diver weights from 1999-00 through 2003-04 assuming that divers were less selective than traps, the same maturity scheduled described above in Section (3.3.1.2), and the average number of broods per female by age.

5.1.2. Results

With the life history parameters of spiny lobster, the yield-per-recruit curve did not reach a maximum at a realistic fishing mortality rate but the maximum yield was 0.43 kg per recruit and the yield-per-recruit in 2003-04 was 0.18 kg at a fishing mortality rate on fully recruited lobsters (age-3) of 0.26 per year (Fig. 5.1.2). The yield-per-recruit at the F20% MSY proxy discussed below was 0.24 kg at a fishing mortality rate of 0.49 per year.

5.2. Stock-Recruitment Models

As noted in Sections 3.2.2.7 and 3.3.2.7, the spawning stock occurs in the Caribbean as well as in Florida but we have no idea how much of Florida's recruitment comes from outside spawning activity and, without estimates of the spawning stock in the western Atlantic, we were unable to determine a stock-recruit relationship.

6. Biological Reference Points (SFA Parameters)

6.1. Existing Definitions and Standards

The existing definition for overfishing was defined in Amendment 6 of the spiny lobster FMP (SAFMC 1998) as a fishing mortality rate (F) in excess of the fishing mortality rate at 20% static SPR (F20%). Static SPR is the equilibrium value associated with any particular fishing and natural mortality rates, selectivties, maturity, and biomass (Mace et al. 1996). Optimum Yield (OY) was defined in Amendment 6 of the spiny lobster FMP as the amount of harvest taken by U.S. fishers while maintaining the Spawning Potential Ratio at or above 30% static SPR. While Maximum Sustainable Yield (MSY) is unknown in this fishery, the Council concluded that the best available data supports using 20% static SPR as a proxy for MSY.

6.2. Estimation Methods

The estimation of Static SPR in terms of eggs per recruit ratio follows the procedures in Gabriel et al. (1989) for calculating spawning stock biomass per recruit with the substitution of the number of eggs per spawning as a function of age for average weight-at-age. Bertelsen and Matthews (2001) gave an expression for the number of eggs as a function of carapace length:

$$E = 91.88 * CL^2 - 231212 \qquad (1)$$

and we used the average numbers of females at length from 1999-00 through 2003-04 catch-at-length matrix from divers as an approximation to the female population size structure to calculate the number of eggs by length and then used the age-length key to convert the numbers of eggs by lengths to the number of eggs by age. Thus the egg per recruit is:

$$EPR = \sum_{a=1}^{15} Ns_a E_a B_a \qquad (2)$$

where Ns_a is the number of females at age, a, at the beginning of the spawning season the following April, E_a is the fecundity or number of eggs produced by a female at age a, and B_a is the number of broods per spawning season one brood for less than 80 mm CL and two for larger female lobsters

(Lipcius 1985). The egg per recruit ratio, *ER*, for a given fishing mortality, *F*, is then:

$$ER = \frac{EPR_F}{EPR_{F=0}}\ . \qquad (3)$$

Table 6.2 lists the selectivity from ICA, average number of eggs, number or broods, and proportion mature by age used to calculate the static SPR.

6.3. Results

Using eggs per recruit as the basis for calculating the static SPR values associated with the estimated fishing mortality rates since 1985-86, the fishing mortality rates exceeded the F20% in 1989-90 and 1991-92, touched F20% in 1995-96 and 2000-01; however, the fishing mortality rates after 2000-01 have been lower and the static SPR values have exceeded 35% (Table 6.3, Fig. 6.3). In the Retrospective Section, we found that ICA tends to underestimate fishing mortality rate especially in the most recent years such that the adjusted fishing mortality rate in 2003-04 could be 0.36 per year (1.37 * 0.26) and the static SPR associated with a fishing mortality rate of 0.36 per year would be 29%.

6.3.1. Overfishing Definitions and Recommendations

The existing overfishing definition is that fishing mortality rates should be no higher than the fishing mortality rate associated with a 20% static SPR (F20%). At the SAW, there was confusion as to the current management objectives and what was used was the definition from Amendment 3 in 1989 that called for keeping the SPR above 5%. The assessment group agreed with using a fishing mortality proxy but thought that 5% was too low and was going to recommend using the average fishing mortality rates from the period 1985-86 through 2000-01 because fishing mortality rates had been stable over this period (Section 3.3.2.6) illustrating that these mortality rates were sustainable. The static SPR associated with the 1985-86 through 2000-01 average fishing mortality rate of 0.52 per year was 19% which was similar to the existing 20% limit. Not surprisingly, fishing mortality rates were higher than F20% or 0.49 per year ten times over the past 19 fishing years (Fig. 6.3.1). These results illustrate the difficulty with using a long-term average as a limit because the limit will be exceeded frequently.

6.3.2. Overfished Definitions and Recommendations

The estimation of conservation and management benchmarks for the south Florida stock of spiny lobster cannot be done reliably *using only the data from the stock assessment, alone.* The reason for this is three-fold:

1) recall that estimation of long term productivity measures such as maximum sustainable yield requires some understanding of the relationship

of future recruitment levels with spawning stock biomass, i.e. the stock-recruitment relationship. In particular one needs to know the curvature of this relationship and at what stock levels recruitment declines. Unfortunately, in this assessment there are no indications of much variation in recruitment trends from the data. Therefore, we cannot estimate benchmarks such as spawning biomass at MSY (SSB_{msy}) or the fishing mortality rate that produces SSB_{msy} (F_{msy}) directly from the data.

2) Even if we *could* estimate SSB_{msy} from the data, the question remains whether this is appropriate because it is quite plausible that some recruitment to the south Florida population comes from other areas throughout the Caribbean (and, indeed, south Florida may contribute recruitment to other areas). Therefore, the extent to which the south Florida population may be treated as a separate breeding population in open to further study.

3) The degree of "leakage" of lobsters outside of the traditional fishery caused by migration, behavior, gear selection or some combination makes the estimates of fishing mortality rates and, subsequently, F_{msy}, to be somewhat uncertain.

Note that by using a surrogate to F_{msy}, the Assessment Group is avoiding the debate on whether recruitment arises from within or without the south Florida area. We only are assuming that there is a breeding population of spiny lobsters of which the south Florida is a component. Then if fishing occurs at F_{msy} throughout the stock, including the south Florida component, then it is expected that SSB_{msy} for the entire breeding stock would be achieved. While current management only controls the U. S. component of the fishery, a F_{msy} strategy for this component would be consistent with overall MSY goals for the stock wherever it occurs. This discussion concurs with Amendment 6 of the spiny lobster FMP that states that MSY is unknown for this species.

6.3.3. Control Rule and Recommendations

A control rule based spawning stock cannot be developed until the spawning biomass of the stock is assessed.

6.4. Status of Stock Declarations

The fishing mortality rates on fully recruited spiny lobsters in 2001-02 and later fishing years have been less than F20%. In 2003-04 the fishing mortality rate on fully recruited spiny lobsters was estimated at 0.26 per year with an associated static SPR of 40% and when we adjust for the retrospective bias, the static SPR would be 29%. Thus, the U.S. fishery is not overfishing based on the F20% management criteria.

As noted in Sections 6.3.2, we need a Caribbean-wide stock assessment to evaluate whether the spiny lobster stock is overfished.

7. Projections and Management Impacts

Because the fishery was not overfishing, we ran only three projection scenarios for spiny lobsters: F = Fcurrent, F = Fmsy, and F = Foy. The duration of the projections was 1.5 mean generation times. A simple equation for average generation time, *GT*, is to weight age by the eggs per recruit (Section 6.2, Equation 2), and the equation is:

$$GT = \frac{\sum_{a=1}^{15} aNs_a E_a B_a}{\sum_{a=1}^{15} Ns_a E_a B_a}. \qquad (1)$$

Equation (1) predicts a mean generation time of 6.26 years but that is time after settlement so including the time spent in the plankton, the generation time was 7.01 (6.26 + 0.75) years. With the mean generation time for spiny lobsters of seven years, the projections were for eleven years beginning in 2004-05 fishing year. The mean generation times would be shorter if we used lipofuscin based growth.

Because of uncertainty in fishing mortality rates, we used the average fishing mortality rate from 2001-02 through 2003-04 fishing years or 0.30 per year for Fcurrent. As noted in Section 6.3.1, The Fmsy proxy (F20%) was equal to 0.49 per year, and Amendment 6 specified F30% for optimum yield and that translates to a fishing mortality rate of 0.35 per year. Recruitment estimated by ICA did not show any trend (t-test for slope equal zero, t = -0.69, df = 17, P = 0.50) and so we used the geometric mean of the time series (16.4 million lobsters) for each future year's recruitment.

The trajectories of biomass and harvests for the three fishing mortality scenarios are shown in Figure 7. At the beginning of the 2004-05 fishing year, the age-structure was not in equilibrium with the fishing mortality rates and the trajectories indicate that it would take about five years to achieve that balance. With the constant recruitment and mortality rates, the biomass was inversely proportional to and harvest was directly proportion to fishing mortality rates. Given the retrospective bias, Fcurrent could be as high as 0.41 per year such that the fishery would still be operating below Fmsy but higher than Foy.

8. Research Recommendations

Tuning indices and lobster growth were the topics discussed during the workshop research needs session. Although specific projects were not developed, the general needs for these topics were discussed and are summarized in this section.

8.1 Tuning Indices

Existing tuning indices are based on a long-term monitoring of post-larvae entering into the Florida Keys; and collection of juvenile surveys conducted as part of research projects; an onboard vessel observer program that ended in 2000; and surveys of lobsters, mostly adults, on the offshore reefs of the keys, again as part of other research efforts. The SAW panel members expressed the need for geographically robust adult and juvenile monitoring programs that could provide tuning indices that can be connected to each other and the fishery. The existing tuning indices do not meet this standard. Broad agreement that this standard is the desired approach was quickly obtained. However, discussion of the details for potentially meeting this need resulted in many ideas and no consensus.

Some discussion occurred regarding the pluses and minuses of fishery dependent vs. fishery independent monitoring and, secondarily, the use of traps vs. dive methods. Each method has its own difficulties; selectivity issues for traps, sampling adequacy for diving, fisherman biases and huge amount of staff effort for an onboard observer program.

We are considering holding a workshop to design possible approaches for developing tuning indices.

8.2 Growth

Discussions regarding growth centered around the lack of growth data from larger (>100 mm CL) lobsters and the impact that this lack of data may have on the assessment. The consensus was that developing growth data on larger lobsters is highly desirable, although everyone recognized the difficulty of doing so in this fishery. Two possible directions emerged: one is to develop collaborations with commercial fishers that fish farther from shore, both in the Gulf of Mexico and west of the Dry Tortugas National Park, to complete some tagging studies. The other is to take advantage of the increasing numbers of larger lobsters inside the no-take areas and attempt some localized tag-recapture studies. Any such studies will require refining existing tagging techniques.

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10. List of Tables

11. List of Figures

11. List of Figures (Continued)

Table 2.1 Numbers of spiny lobster by carapace length, gear, and fishing year.

TRAPS Females

CL	Fishing year 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	706	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	1336	215	355	992	0	101	102	0	0	0	0	2330	0	737	403	0	139	293	151
71	60276	127017	74250	94594	34704	36574	25790	25593	30104	19807	20886	36494	20118	14445	28860	13116	6662	3824	6607
76	694799	319636	799182	1090170	1059089	871782	907119	717602	772883	1106618	889985	1292796	1432914	668447	956054	621795	279092	494306	479231
81	628576	279381	642366	971443	878993	659181	818271	670194	582239	726847	779474	876274	822647	529373	825606	548362	298272	541771	471181
86	343106	323710	364179	451005	639794	415957	406759	377529	332299	439899	558914	457152	309599	314218	441473	252873	166272	245197	261513
91	163878	216016	154964	172953	300475	248550	188109	146275	120307	185108	244157	181911	117482	161949	173802	135877	96610	121242	130268
96	72242	294642	76641	83570	112933	96996	80529	51423	42558	68907	110104	70236	45659	70669	91943	70908	51648	49364	66647
101	22622	21767	22979	33222	46207	34928	40566	25758	13828	41286	34365	32782	32282	22918	32088	36671	29770	18531	33827
106	5393	6157	8504	8352	11882	9542	4504	10271	3140	10682	17792	19111	16280	10461	13260	26362	17188	9757	14667
111	3691	2843	1510	1769	1327	9652	2692	8878	3896	4722	9367	6703	10864	7339	3317	15610	10225	5571	4698
116	4110	1913	4989	664	2191	3180	3352	3910	4964	5595	5050	4736	6707	6132	5955	13699	7181	3898	3316
121	3207	1298	2094	944	1004	2993	2941	4012	1035	4298	5850	4126	3493	4110	2333	10737	5571	2497	1546
126	3804	748	2482	431	419	1640	1757	2686	1787	2187	2963	2720	1725	3775	1211	6702	3080	1512	636
131	1856	1304	1009	466	299	1918	1137	1207	477	2067	1017	941	1898	673	2051	4737	5193	1383	630
136	4778	1625	3219	492	557	1496	1306	1717	439	1118	1864	743	1426	1010	247	3537	3191	572	0
141	1571	214	1139	123	120	303	394	645	612	121	2045	80	574	672	62	2666	1135	380	0
146	662	321	204	185	180	277	476	576	165	516	1786	120	12	705	93	1253	677	174	0
151	0	0	0	0	0	0	62	118	0	212	0	0	565	0	0	535	364	143	0
156	0	0	0	0	0	0	0	0	0	0	0	0		335	0	0	0	0	0
161	0	0	0	0	0	0	0	0	0	212	0	0	0	0	0	217	0	0	0
166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0
181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2015907	1598807	2160066	2912081	3090174	2395070	2485866	2048394	1910733	2620202	2685619	2989255	2824245	1817968	2578758	1765657	982270	1500463	1474918

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

TRAPS Males

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	0	0	0
66	377	215	334	706	0	0	0	0	0	0	0	0	503	369	1253	0	133	101	0
71	15684	16063	9483	48342	18896	21018	11166	8826	9857	12410	6682	6923	24494	11533	6284	2982	3769	3150	2986
76	570695	269525	566594	874597	747603	719956	589878	572651	750848	984526	523183	681225	1007056	533694	812077	440170	231918	373300	345680
81	635684	296636	637603	985559	825618	663380	768802	614329	753185	938231	616555	910700	1054628	590986	944089	557928	266120	547537	431102
86	488736	368743	525115	634918	689681	492528	783050	475406	528870	661883	631270	787499	740526	436910	679566	370458	181707	410918	321385
91	311043	289540	293481	406680	562953	344213	458231	304593	329259	345640	426057	465189	347824	322046	465463	249542	145991	264985	233913
96	173459	292709	198298	214227	273083	177303	195825	175885	132507	208083	251934	267052	192692	147515	205263	150833	79496	141671	134059
101	86837	368505	110493	77945	142448	97866	129531	70899	53596	109208	128238	107530	73018	80712	124359	101707	51580	51734	81276
106	38097	225759	34570	37260	68194	52163	49138	30769	18605	56771	57662	54873	46036	38855	57637	42050	20175	28269	36103
111	17371	18621	15831	23436	20336	35641	37953	20673	12208	35694	38928	27219	19113	19399	22649	24432	14829	17445	19727
116	5866	4349	7738	10941	10924	5793	5433	7376	6468	10079	9420	15060	11110	14801	17386	20582	10234	7381	9571
121	2529	6312	3439	1243	3072	8040	4693	4769	7701	7944	6977	7726	8154	10177	10731	11048	4389	3518	3954
126	2032	170	962	824	976	4853	1564	3582	3857	6028	7740	2582	5092	10647	5172	11559	4412	2938	1803
131	1785	3285	1404	2878	1149	4828	2265	4267	2366	3905	5644	4502	4956	5237	3030	7643	4964	2869	942
136	1710	1752	1030	244	277	1776	2247	2341	1307	2680	4855	2838	3966	6599	1117	7386	4104	1989	1110
141	1162	876	941	1595	138	874	1707	1681	1560	1702	5122	462	4306	2349	352	3899	3180	2464	613
146	1883	64	1671		79	629	803	1238	803	1518	2124	1060	2785	1006	321	1692	1847	1384	782
151	974	170	737	182	138	432	742	1026	663	184	3444	1203	1700	3027	1224	2728	1297	836	625
156	911	107	681	182	60	160	785	1470	1870	643	1910	761	508	1678	551	1661	3082	677	306
161	377	769	334			101	682	756	1304	212	1035	422		671	703	1271	1340	537	0
166	0	0	0	0	0	0	62	534	1401	335	1532	422	0	0	0	1099	363	95	313
171	0	0	0	0	0	0	145	104	203	459	1035	422	503	671	0	265	364	138	0
176	377	0	334	0	0	0	0	274	0	0	840	1163	0	0	0	172	268	48	0
181	0	0	0	0	0	0	0	0	0	547	148	0	0	0	0	149	210	48	0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		77	48	0
191	221	107	68	62	60	58	125	153	55	60	35	40	4	0	31	101	66	30	0
196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2357810	2164277	2411141	3321821	3365685	2631612	3044827	2303654	2618493	3388742	2732370	3346873	3548974	2238882	3359258	2011357	1035915	1864110	1626250

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

DIVERS Females

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	50	81	74	78	54	79	231	443	335	76	230	374	384	0	298	0	98	0	0
71	7506	1949	1098	1435	1252	1204	2215	3196	1727	1574	435	2397	3181	2347	5391	1327	2069	1599	8
76	19281	16392	7811	14915	16026	9908	21116	31699	12636	30810	25522	43384	46792	33444	68808	61554	18389	44987	29246
81	20677	14968	8559	15097	18604	10486	25189	20310	12622	18725	34982	38088	33464	41883	60678	62958	24809	59041	40553
86	10145	7648	5416	8639	11496	6540	14968	14514	8268	11738	24318	16446	20904	25125	31056	40076	21567	25564	24905
91	5363	7610	3468	5489	5705	4308	7773	7242	6026	6413	6817	7764	11587	13866	12214	23108	18021	25230	17969
96	1697	3585	2011	3030	4943	2518	4742	4403	3248	2829	17433	5399	9792	4742	11820	16970	16847	18839	12588
101	504	1270	916	1329	1799	1182	1533	2642	1345	1931	1714	2371	3535	2899	5646	14646	9543	6787	8118
106	254	367	458	643	2849	581	925	1717	724	1527	1566	1418	1949	254	3538	2652	6264	2095	4172
111	272	253	203	309	260	247	558	1014	1018	710	567	852	1398	259	868	221	1553	2090	759
116	121	115	98	145	104	130	327	662	637	653	1201	608	630	91	556	0	993	1280	1219
121	43	25	18	38	31	32	126	298	615	554	277	301	330	45	337	0	880	0	232
126	43	26	19	38	32	33	130	307	570	465	284	310	340	45	347	0	1379	0	232
131	14	16	19	23	11	24	145	351	308	620	298	341	385	0	387	0	1498	0	0
136	48	79	71	74	52	75	205	380	402	431	176	312	315	0	228	0	716	253	0
141	7	7	9	11	5	11	67	162	308	177	138	157	178	0	178	0	193	0	0
146	5	5	6	8	4	8	48	117	188	266	99	114	128	0	129	0	262	0	0
151	6	6	8	9	5	10	60	144	257	89	122	140	158	0	159	0	331	0	0
156	4	4	5	6	3	6	37	90	51	266	76	87	99	0	99	0	193	0	0
161	4	5	6	7	3	8	45	108	103	0	92	105	118	0	119	0	0	0	0
166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	2	2	3	4	2	4	22	54	0	89	46	52	59	0	59	0	0	0	0
176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	66046	54413	30276	51327	63240	37394	80462	89853	51388	79943	116393	121020	135726	125000	202915	223512	125605	187765	140001

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

DIVERS Males

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	39	69	60	60	45	60	119	173	78	76	1	111	88	0	0	0	0	173	0
71	2163	748	612	758	606	675	1177	1674	802	859	130	1415	1740	448	4203	1329	492	1503	667
76	21342	10265	5377	10561	13846	6928	18452	33061	8254	33005	12643	36808	31421	16983	47878	59233	15295	35484	16509
81	22824	10985	7331	14198	13529	9487	21728	23316	14456	30934	24638	36408	46149	31876	73257	85607	20889	56726	32425
86	14835	8987	6439	11138	11192	7921	19455	12971	9939	18944	23900	25994	27840	33547	53284	47921	17912	47789	27274
91	8054	8567	6665	10103	10018	7878	18083	19481	10253	13210	21042	19729	19823	31733	32221	33687	20657	37999	22825
96	8919	6382	3817	5995	8702	4727	8591	9788	5570	10894	12687	14119	16084	18626	26517	25546	15047	24308	24111
101	2302	3662	2504	3733	6854	3075	4346	5546	3434	3929	9885	6079	8240	10700	13170	14007	15794	16229	14454
106	822	1341	1057	1865	1429	1483	1990	1595	1406	1292	1001	2070	8699	3886	4881	14873	11350	15312	7258
111	816	2154	1057	1461	2133	1270	2124	2464	2120	1375	1715	1944	2910	1827	6509	1553	5569	6637	3981
116	420	1505	386	625	390	510	1135	1201	1001	551	535	960	1434	1656	684	3539	2359	2065	5482
121	349	258	206	388	954	295	536	999	1382	828	700	1206	922	1603	1658	1105	2910	271	1411
126	75	39	23	59	54	46	148	345	468	399	339	357	384	91	397	0	1831	27	0
131	309	262	177	284	286	219	486	830	1029	919	446	690	681	826	521	0	2059	27	0
136	109	54	28	82	78	63	181	418	417	1041	425	439	467	136	486	0	1486	0	0
141	117	111	85	123	101	110	289	572	495	652	386	521	531	91	456	0	2405	0	0
146	47	30	23	44	34	39	167	398	360	377	361	397	439	45	446	0	2069	0	0
151	8	9	11	13	6	14	82	198	433	177	168	192	217	0	218	0	840	0	0
156	13	14	17	21	10	22	130	315	513	177	267	306	345	0	347	0	840	0	0
161	14	16	19	23	11	24	145	351	308	443	298	341	385	0	387	0	279	0	0
166	3	3	3	4	2	4	26	63	194	0	53	61	69	0	69	0	262	0	0
171	34	16	7	24	25	18	41	91	331	22	101	100	103	45	109	0	321	0	0
176	4	4	5	6	3	6	37	90	205	0	76	87	99	0	99	0	193	0	0
181	4	5	6	7	3	8	45	108	103	89	92	105	118	0	119	0	140	0	0
186	3	4	4	5	3	6	34	81	114	0	69	79	89	0	89	0	85	0	0
191	2	2	3	4	2	4	22	54	51	0	46	52	59	0	59	0	140	0	0
196	2	2	3	4	2	4	22	54	0	0	46	52	59	0	59	0	140	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	2	2	3	4	2	4	22	54	51	0	46	52	59	0	59	0	0	0	0
Total	83631	55496	35928	61592	70320	44900	99613	116291	63767	120193	112096	150674	169454	154119	268182	288400	141364	244550	156397

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

OTHER Females

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	389	193	14	94	35	34	335	102	151	77	68	126	538	732	1301	678	277	118	33
76	8175	11207	2805	4612	8320	6270	13694	1158	2253	2667	2678	5268	15424	17824	21184	17329	2278	2052	2408
81	9073	11784	2870	4903	8585	6312	10702	1320	2682	2506	2833	5479	17328	23334	35282	19351	2836	3536	4199
86	5286	7039	1768	2875	5094	3963	8149	820	1503	2359	1946	3501	10528	19926	16342	11084	2184	2418	2660
91	1806	2304	578	934	1611	1322	1576	315	507	1146	711	1221	3563	2690	2617	8662	942	1300	111
96	498	593	151	233	382	364	851	108	133	68	250	367	1030	1125	808	1645	203	503	369
101	1174	1556	386	640	1133	866	1025	177	331	899	390	751	2215	925	1091	2179	308	556	62
106	313	321	72	132	197	188	40	71	73	23	101	182	415	350	417	736	123	227	6
111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
116	313	321	72	132	197	188	40	71	73	23	101	182	415	350	417	736	123	227	6
121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	27027	35318	8716	14555	25554	19507	36412	4142	7706	9768	9078	17077	51456	67256	79459	62400	9274	10937	9854

OTHER Males

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	390	194	15	94	35	34	386	102	156	83	75	131	581	252	851	1003	283	129	37
76	6826	9403	2336	3896	7053	5170	6352	912	1905	1422	2072	4260	12712	24028	28908	22480	1539	2193	2330
81	9694	13367	3288	5583	10119	7183	7714	1214	2767	2581	2692	5814	17894	35379	32622	32878	3473	2498	3798
86	8174	11110	2743	4611	8290	6082	9189	1114	2285	2119	2483	5036	15153	20238	15618	21534	3296	2396	3730
91	4593	5925	1452	2442	4263	3314	6006	731	1242	1522	1551	2870	8365	3937	7718	25040	1629	1159	1881
96	2958	3960	976	1643	2927	2148	4198	412	854	1481	941	1820	5692	21406	3487	9387	1092	398	493
101	964	1201	286	505	861	607	1132	139	316	423	281	554	1916	5879	1249	1582	664	184	70
106	1148	1560	400	634	1131	864	1956	170	365	619	461	796	2604	6699	1373	2500	346	653	99
111	391	340	71	141	176	168	366	93	132	72	139	219	713	376	968	1159	229	517	34
116	313	321	72	132	197	188	40	71	73	265	101	182	415	350	417	736	123	31	6
121	195	103	12	47	17	17	346	51	92	60	60	83	420	606	161	339	160	98	31
Total	35646	47484	11651	19728	35069	25775	37685	5009	10187	10647	10856	21765	66465	119150	93372	118638	12834	10256	12509

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

BAIT Females

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	23518	33969	13285	12898	15174	27219	16968	14527	11189	10783	18272	15465	10904	11172	13557	10618	0	480	2018
56	42033	60713	23744	23053	27121	48648	30328	25964	20554	21583	25323	27397	24672	18648	26672	21840	12084	11031	4035
61	81694	117999	46148	44805	52712	94551	58944	50462	39108	43829	43971	55094	51637	28825	53882	41262	39704	35969	12106
66	150444	217299	84984	82510	97071	174119	108547	92928	67828	81651	78430	94359	113066	41111	86022	72007	55815	60908	60528
71	234624	338889	132536	128678	151387	271547	169285	144926	102954	125545	133022	134670	185121	54164	99990	104505	58117	66663	76668
76	12010	11183	5603	3568	4225	9573	6190	4838	2236	4852	4037	8130	3964	2560	3606	3067	1772	1940	1833
81	6686	6225	3119	1986	2352	5329	3446	2693	1203	2915	2401	4615	1974	1585	1625	1474	1060	1121	973
86	3698	3443	1725	1099	1301	2947	1906	1489	572	1821	1602	2549	872	769	930	637	664	615	337
91	1744	1624	814	518	614	1390	899	703	242	922	851	1146	355	295	415	302	348	301	112
96	721	672	336	214	254	575	372	291	77	400	404	429	142	137	187	143	221	169	0
101	282	263	132	84	99	225	145	114	33	135	166	185	49	35	74	35	32	24	0
Total	557454	792279	312426	299413	352310	636123	397030	338935	245996	294436	308479	344039	392756	159301	286960	255890	169817	179221	158610

BAIT Males

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	20967	30285	11844	11499	13529	24267	15128	12951	10510	8873	16952	12344	10279	9402	10555	9429	575	1439	4035
56	34382	49661	19422	18857	22184	39793	24807	21238	17479	17519	22458	21566	17918	15736	20352	15856	8631	11510	18158
61	57237	82673	32333	31391	36931	66245	41298	35355	29329	30083	30949	38647	32833	22518	35173	26917	34525	33571	20176
66	94081	135890	53145	51598	60704	108887	67881	58113	46006	50225	48606	61781	62002	27894	61625	45815	44307	47000	42369
71	144018	208018	81354	78986	92925	166682	103911	88959	68974	80437	77125	88053	97960	35498	74487	62679	56966	65704	76668
76	8694	8095	4056	2583	3058	6930	4481	3502	1777	3671	2403	6180	2877	1863	3727	2425	1819	2326	2918
81	6107	5687	2849	1815	2148	4868	3148	2460	1147	2548	1971	4228	1990	1449	2189	1738	1946	2519	3218
86	4311	4014	2011	1281	1516	3436	2222	1736	706	1886	1558	3161	1303	1104	1386	1143	1693	1736	1384
91	2867	2670	1337	852	1009	2285	1478	1155	413	1421	1193	2122	710	682	886	610	997	1024	823
96	1586	1477	740	471	558	1264	818	639	187	860	805	1069	325	371	561	349	1107	1097	786
101	907	844	423	269	319	723	467	365	93	481	537	502	186	158	248	188	712	711	524
Total	375157	529314	209514	199602	234881	425380	265639	226473	176621	198004	204557	239653	228383	116675	211189	167149	153278	168637	171059

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

RECREATIONAL Females

	Fishing year																		
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	1384	1295	1520	2088	3768	836	0	0	1059	0	0	0	0	0	0	0	897	0	0
66	2769	2590	3040	4177	0	1671	662	0	2119	1778	0	466	0	592	945	0	449	1341	0
71	26301	24602	22800	48032	18839	20058	27795	4962	3178	5333	3678	9778	7542	3550	6616	8289	4038	13659	9509
76	184803	172864	186964	300723	263750	214784	293176	162509	234661	241192	230471	279835	317693	179842	324186	257875	154333	163797	141118
81	135660	126896	141363	215101	239259	212277	248836	160028	249493	205635	220664	212787	323350	195223	303393	193406	141322	146171	155192
86	53295	49852	69921	64739	97964	114496	98608	81875	90051	90669	89491	75430	109354	82230	102076	77362	60118	77687	76455
91	15227	14243	22800	14618	33911	36772	23163	38456	19599	20741	15324	16762	25453	23663	33080	15657	12113	30921	21681
96	4845	4532	9120	2088	15071	9193	8603	7443	5827	7704	3678	3259	6599	7099	7561	5526	2243	9846	7227
101	2076	1942	3040	2088	1884	4179	2647	3722	3708	1185	613	931	0	1775	5671	3684	0	3408	1141
106	0	0	0	0	0	836	1324	1241	530	593	613	466	943	592	0	921	0	349	0
111	0	0	0	0	0	836	662	0	1059	1185	0	0	0	0	0	0	0	126	761
116	1384	1295	1520	2088	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
121	0	0	0	0	0	0	662	1241	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0	592	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
161	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	427744	400111	462088	655742	674446	615938	706138	461477	611284	576015	564532	599714	790934	495158	783528	562720	375513	447305	413084

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

RECREATIONAL Males

CL	Fishing year 1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	692	647	0	2088	1884	1671	0	0	2119	0	0	0	0	0	0	0	0	223	0
66	5537	5179	0	16707	0	4179	0	0	3708	593	0	466	943	1775	0	0	0	2137	380
71	22149	20718	19760	39679	15071	19222	20516	3722	7946	7111	1226	8847	2828	7099	1890	4605	1795	11620	7607
76	240866	225305	255365	375904	252447	158790	270675	96761	262736	269637	163046	298926	281870	104119	322296	304845	144463	162557	117155
81	213873	200056	238645	317430	231723	178848	344134	212130	339014	330083	337125	370631	426105	166827	473519	405231	205927	211743	199696
86	131507	123012	170243	162892	241143	216456	333546	203446	260617	260748	276442	257486	338433	178067	361992	278136	178560	166275	172689
91	49834	46615	60801	66827	154482	138732	160817	132736	153616	153486	178370	128976	193256	109443	172017	157488	89728	99609	114492
96	24917	23307	24320	41767	56518	69366	59562	57064	68332	56298	64360	43302	75417	46735	69941	70916	44864	46971	52491
101	11766	11006	21280	6265	24491	28415	21839	17367	22777	17186	22066	13968	16026	18931	27409	19341	11216	19358	19019
106	4153	3885	6080	4177	5652	10029	7942	7443	7416	3556	3678	3259	9427	2958	11342	5526	3589	7262	6466
111	692	647	1520	0	5652	5014	5294	4962	3708	3556	1226	931	0	7099	5671	2763	897	4050	1902
116	692	647	0	2088	0	1671	2647	1241	1589	1185	1839	931	943	0	3781	0	449	1466	761
121	0	0	0	0	0	0	1985	0	1589	1185	0	931	943	592	945	0	449	223	0
126	692	647	1520	0	0	0	1324	1241	0	593	1226	0	943	0	945	0	449	0	380
131	0	0	0	0	0	0	662	0	0	593	0	0	0	592	0	0	449	0	0
136	0	0	0	0	0	836	0	0	0	593	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	0
156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
161	0	0	0	0	0	0	0	1241	0	0	0	0	0	0	0	0	0	0	0
166	0	0	0	0	0	0	0	0	0	0	0	0	0	592	0	0	0	0	0
171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	0	0	0	0	0	0	0	1241	0	0	0	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	0	0	0	0	0	0	0	1241	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	707370	661671	799534	1035824	989063	833229	1230943	741836	1135167	1106403	1050604	1128654	1347134	644829	1451748	1248851	682835	733620	693038

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

Special Recreational License				Females					Fishing year										
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	13	26	47	34	21	44	65	85	118	26	59	70	60	0	36	0	12	0	0
71	2006	631	697	634	487	666	624	610	609	542	111	446	500	379	653	96	253	148	1
76	5154	5306	4955	6590	6239	5483	5952	6049	4455	10604	6500	8067	7358	5398	8329	4434	2251	4174	3635
81	5527	4845	5430	6670	7242	5802	7100	3876	4450	6445	8910	7082	5262	6760	7345	4535	3036	5478	5040
86	2712	2476	3436	3817	4475	3619	4219	2770	2915	4040	6194	3058	3287	4055	3759	2887	2640	2372	3095
91	1434	2463	2200	2425	2221	2384	2191	1382	2125	2207	1736	1444	1822	2238	1479	1665	2206	2341	2233
96	454	1160	1276	1339	1924	1393	1337	840	1145	974	4440	1004	1540	765	1431	1223	2062	1748	1564
101	135	411	581	587	700	654	432	504	474	665	437	441	556	468	683	1055	1168	630	1009
106	68	119	291	284	1109	321	261	328	255	526	399	264	306	41	428	191	767	194	518
111	73	82	129	137	101	137	157	194	359	244	144	158	220	42	105	16	190	194	94
116	32	37	62	64	40	72	92	126	225	225	306	113	99	15	67	0	122	119	151
121	11	8	11	17	12	18	36	57	217	191	71	56	52	7	41	0	108	0	29
126	11	8	12	17	12	18	37	59	201	160	72	58	53	7	42	0	169	0	29
131	4	5	12	10	4	13	41	67	109	213	76	63	61	0	47	0	183	0	0
136	13	26	45	33	20	42	58	73	142	148	45	58	50	0	28	0	88	23	0
141	2	2	6	5	2	6	19	31	109	61	35	29	28	0	22	0	24	0	0
146	1	2	4	4	2	4	14	22	66	92	25	21	20	0	16	0	32	0	0
151	2	2	5	4	2	6	17	27	91	31	31	26	25	0	19	0	41	0	0
156	1	1	3	3	1	3	10	17	18	92	19	16	16	0	12	0	24	0	0
161	1	2	4	3	1	4	13	21	36	0	23	20	19	0	14	0	0	0	0
166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	1	1	2	2	1	2	6	10	0	31	12	10	9	0	7	0	0	0	0
176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	17654	17613	19207	22677	24619	20692	22679	17147	18119	27515	29644	22503	21343	20176	24563	16102	15373	17422	17399

Table 2.1 (continued). Numbers of spiny lobster by carapace length, gear, and fishing year.

Special Recreational License				Males				Fishing year											
CL	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	10	22	38	27	18	33	34	33	28	26	0	21	14	0	0	0	0	16	0
71	578	242	388	335	236	374	332	319	283	296	33	263	274	72	509	96	60	139	83
76	5705	3323	3411	4666	5390	3834	5201	6309	2910	11360	3220	6844	4941	2741	5796	4267	1872	3292	2052
81	6101	3556	4651	6273	5267	5250	6124	4449	5097	10647	6275	6770	7257	5145	8868	6167	2557	5263	4030
86	3965	2909	4085	4921	4357	4383	5484	2475	3504	6520	6087	4833	4378	5415	6450	3452	2192	4434	3390
91	2153	2773	4228	4464	3900	4359	5097	3718	3615	4547	5359	3668	3117	5122	3900	2427	2528	3526	2837
96	2384	2066	2422	2649	3388	2616	2421	1868	1964	3750	3231	2625	2529	3006	3210	1840	1842	2255	2996
101	615	1185	1589	1649	2668	1702	1225	1058	1211	1352	2518	1130	1296	1727	1594	1009	1933	1506	1796
106	220	434	671	824	556	821	561	304	496	445	255	385	1368	627	591	1071	1389	1421	902
111	218	697	671	645	830	703	599	470	747	473	437	361	458	295	788	112	682	616	495
116	112	487	245	276	152	282	320	229	353	190	136	179	225	267	83	255	289	192	681
121	93	84	131	171	371	163	151	191	487	285	178	224	145	259	201	80	356	25	175
126	20	13	15	26	21	25	42	66	165	137	86	66	60	15	48	0	224	3	0
131	83	85	112	125	111	121	137	158	363	316	114	128	107	133	63	0	252	3	0
136	29	17	18	36	30	35	51	80	147	358	108	82	73	22	59	0	182	0	0
141	31	36	54	54	39	61	81	109	175	224	98	97	84	15	55	0	294	0	0
146	13	10	15	19	13	22	47	76	127	130	92	74	69	7	54	0	253	0	0
151	2	3	7	6	2	8	23	38	153	61	43	36	34	0	26	0	103	0	0
156	3	5	11	9	4	12	37	60	181	61	68	57	54	0	42	0	103	0	0
161	4	5	12	10	4	13	41	67	109	152	76	63	61	0	47	0	34	0	0
166	1	1	2	2	1	2	7	12	68	0	13	11	11	0	8	0	32	0	0
171	9	5	4	11	10	10	12	17	117	8	26	19	16	7	13	0	39	0	0
176	1	1	3	3	1	3	10	17	72	0	19	16	16	0	12	0	24	0	0
181	1	2	4	3	1	4	13	21	36	31	23	20	19	0	14	0	17	0	0
186	1	1	3	2	1	3	10	15	40	0	18	15	14	0	11	0	10	0	0
191	1	1	2	2	1	2	6	10	18	0	12	10	9	0	7	0	17	0	0
196	1	1	2	2	1	2	6	10	0	0	12	10	9	0	7	0	17	0	0
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	1	1	2	2	1	2	6	10	18	0	12	10	9	0	7	0	0	0	0
Total	22355	17963	22793	27212	27375	24845	28077	22192	22484	41369	28550	28017	26647	24875	32464	20776	17302	22690	19437

Table 2.2. Numbers of spiny lobster by age after settlement (yr), gear, and fishing year.

TRAPS Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	199671	138456	227107	312343	271578	224253	234055	188707	197529	266403	226291	320733	336433	167152	245883	157582	73795	127599	122306
2	825547	483245	900517	1254106	1231530	957742	1038428	848885	824176	1110799	1055380	1297815	1294934	734935	1077871	697992	357224	615906	580508
3	570235	436802	604482	821628	903258	677193	713038	591273	543449	732671	781805	828775	752182	514871	737839	479800	271281	436732	424499
4	248299	275152	256908	331882	415995	312439	304319	251799	218831	306144	361607	330964	269289	230319	312630	215233	135559	189318	197277
5	94725	148303	96852	118657	163332	127433	114477	93002	75851	114480	144441	119641	91529	91741	117692	91837	62361	72288	82454
6	35379	66774	36475	43447	62024	49904	43085	34756	26043	43722	56390	45451	34936	35979	45094	41019	28847	27912	34914
7	15007	27647	15841	16688	24299	21166	17855	15546	11244	19616	24605	20353	17847	17007	20124	25042	16769	12928	16500
8	6343	10569	6694	6508	9481	9141	7390	7185	4944	8720	10802	9156	8953	7865	8767	13395	8771	5946	7539
9	2631	3915	2746	2536	3660	3951	2960	3298	2132	3747	4739	4086	4298	3536	3713	6591	4266	2685	3337
10	2058	1838	1788	1266	1724	2592	2045	2691	1270	2887	3821	3062	3085	2826	2309	6377	3689	1966	1941
11	3578	1322	2553	867	1067	2483	2263	3297	1840	3093	4136	3480	2913	4057	2057	8249	4208	2106	1435
12	1612	600	1163	397	494	1207	1092	1589	838	1538	2043	1669	1466	1901	1020	4062	2092	1031	706
13	957	366	680	249	300	785	730	1037	453	1054	1403	1082	961	1175	661	2721	1409	671	448
14	644	228	446	155	180	505	483	684	287	692	926	709	608	778	416	1802	923	434	274
15	355	125	243	85	97	280	271	381	153	389	521	394	335	429	229	1009	516	241	149
Unaged	8867	3464	5571	1266	1156	3994	3375	4263	1693	4246	6712	1884	4475	3395	2453	12945	10560	2700	630
Total	2015907	1598807	2160066	2912081	3090174	2395070	2485866	2048394	1910733	2620202	2685619	2989255	2824245	1817968	2578758	1765657	982270	1500463	1474918

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

TRAPS Males

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	620198	317525	616844	959359	817628	725710	704855	607404	766833	984463	596031	801664	1052917	574897	881075	490875	250870	451624	388142
2	1008856	681485	1027577	1448027	1421146	1095082	1326843	985304	1156368	1444932	1128175	1455746	1560751	939195	1446734	820330	415108	815523	676858
3	449419	541314	469608	590180	690918	481745	625764	435564	453946	585160	578480	671243	597996	421274	632333	379810	197951	367955	327041
4	166350	333549	178105	201485	269341	185348	231771	158594	144633	211282	234462	246169	194399	158660	231964	154901	81789	132288	132912
5	62101	165962	67404	71642	101099	74637	86678	59134	48287	83047	93670	92027	69493	62374	88429	66645	34841	48945	54378
6	24198	71942	26257	26980	38285	32711	34855	24037	19365	36202	39943	37178	28868	29098	37774	33066	16629	19908	23280
7	9875	28375	10494	10990	15005	14665	14196	10534	8704	16553	17994	16021	13217	15182	17316	17790	8581	8863	10321
8	4198	10690	4392	4663	6109	6864	5957	4919	4420	7873	8424	7380	6516	8267	8508	9747	4527	4181	4743
9	1845	3946	1886	1992	2530	3272	2523	2367	2302	3816	4085	3431	3269	4535	4220	5318	2383	2016	2190
10	1121	2065	1057	1343	1243	2394	1476	1870	1569	2485	2923	2364	2460	3219	2543	4023	2051	1449	1146
11	1034	1851	891	1462	871	2570	1335	2160	1460	2315	3043	2450	2652	3089	2087	4197	2466	1533	789
12	1471	1841	1002	806	542	2239	1919	2374	1451	2642	4256	2784	3553	5307	1616	6281	3548	1873	1001
13	657	875	459	473	273	1136	850	1146	696	1233	1936	1310	1629	2313	803	2820	1623	874	434
14	403	523	275	265	150	669	522	692	412	742	1190	791	998	1438	459	1740	1002	531	261
15	179	241	124	134	71	316	231	320	189	337	534	361	450	631	215	775	451	242	114
Unaged	5905	2093	4766	2021	475	2254	5051	7236	7859	5660	17225	5955	9806	9402	3182	13037	12094	6305	2639
Total	2357810	2164277	2411141	3321821	3365685	2631612	3044827	2303654	2618493	3388742	2732370	3346873	3548974	2238882	3359258	2011357	1035915	1864110	1626250

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

DIVERS Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	8496	5007	2565	4471	4761	3133	6699	9201	4230	7889	7214	11981	12814	9874	19547	16044	5964	12673	7854
2	27336	20172	10825	19164	22166	13367	29789	33619	16875	30713	38566	48832	50558	48080	79541	78533	31154	64080	44609
3	17758	14949	8407	14319	17456	10355	22796	23053	13087	20393	33417	32611	35870	37155	54866	62789	31321	52402	39042
4	7572	7730	4403	7149	9212	5436	11214	11152	7079	9346	18052	14193	17764	17845	25157	34151	22132	29291	22930
5	2836	3588	2073	3241	4627	2577	4922	5214	3481	4156	8994	5942	8460	7230	11223	16933	13529	14904	12088
6	1041	1545	946	1440	2423	1185	2116	2491	1604	1945	4171	2615	3950	2810	5297	8264	7544	6968	6180
7	451	700	474	707	1286	599	1066	1507	1037	1223	2305	1463	2131	1136	2763	3897	4353	3726	3540
8	203	308	225	333	619	286	514	807	581	660	1102	750	1074	465	1335	1732	2200	1836	1762
9	92	132	103	152	293	131	239	400	295	327	491	361	515	186	616	718	1041	850	810
10	55	65	53	81	150	70	149	284	327	323	310	262	342	87	383	284	745	396	443
11	58	48	38	65	89	56	164	357	567	493	358	347	405	68	420	107	1266	204	378
12	27	22	18	30	39	26	77	167	265	233	171	162	188	30	191	39	550	103	177
13	16	12	9	16	19	14	44	98	167	149	100	96	109	17	110	14	303	49	99
14	10	7	5	10	10	8	28	63	113	99	63	62	70	10	70	5	202	22	59
15	5	3	3	5	5	4	15	34	63	55	34	34	38	5	38	2	109	10	31
Unaged	90	124	127	142	85	146	629	1406	1617	1938	1047	1308	1440	0	1358	0	3193	253	0
Total	66046	54413	30276	51327	63240	37394	80462	89853	51388	79943	116393	121020	135726	125000	202915	223512	125605	187765	140001

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

DIVERS Males

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	23734	11544	6973	12983	14668	8830	21647	30889	11564	32950	18567	38382	38490	25029	61930	69809	18671	46755	24176
2	34451	20125	13499	23833	25316	16839	39527	42770	22437	47828	43868	59872	65240	60748	108725	116608	40190	93802	55051
3	15062	11653	8016	13052	15255	9848	20758	21176	12489	20955	26515	28304	32795	37327	53606	55749	29995	54082	36926
4	5681	5781	3786	5941	7567	4682	8740	9303	5767	8069	11674	11380	15238	16683	22274	25010	18345	26738	19870
5	2248	2874	1733	2699	3594	2175	3739	4156	2905	3301	4746	4750	7275	7064	9700	11505	10224	12821	10075
6	957	1470	817	1283	1784	1043	1765	2095	1765	1564	2070	2256	3497	3220	4543	5221	5879	5842	5089
7	427	773	380	605	809	494	867	1071	1001	775	918	1094	1675	1470	2053	2421	3211	2602	2628
8	209	400	182	295	397	240	443	578	591	418	442	580	816	744	976	1152	1765	1121	1374
9	102	194	84	140	191	113	219	302	328	225	221	303	391	368	461	529	950	463	675
10	105	134	70	115	144	91	190	298	355	280	187	276	303	326	310	232	848	189	307
11	144	141	86	140	156	109	237	395	486	415	224	343	347	409	304	101	1029	82	136
12	131	95	56	113	119	87	216	429	472	803	353	417	433	270	425	40	1352	32	56
13	67	51	32	59	62	46	109	210	238	353	159	197	202	151	190	16	630	13	22
14	40	29	18	35	36	27	65	127	143	223	99	120	124	87	117	6	386	6	9
15	19	14	9	17	17	13	31	59	67	98	44	55	56	43	52	2	175	2	3
Unaged	253	218	189	282	204	263	1062	2429	3158	1937	2009	2345	2572	181	2516	0	7714	0	0
Total	83631	55496	35928	61592	70320	44900	99613	116291	63767	120193	112096	150674	169454	154119	268182	288400	141364	244550	156397

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

OTHER Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	2268	2914	709	1209	2103	1581	3424	345	655	693	708	1384	4195	5065	6600	4743	728	641	705
2	10678	14096	3476	5825	10290	7730	15219	1577	3063	3481	3477	6682	20326	26968	33864	23223	3441	3690	4076
3	7741	10204	2528	4203	7412	5635	10613	1168	2220	2819	2629	4921	14960	21065	24300	17920	2711	3185	3154
4	3493	4565	1135	1872	3283	2549	4473	550	995	1504	1242	2261	6793	9081	9573	9002	1324	1717	1293
5	1402	1804	448	737	1280	1020	1619	232	393	677	515	918	2699	3053	3022	3880	543	793	418
6	621	784	194	320	550	446	617	107	171	314	227	404	1159	1047	1028	1664	229	373	135
7	410	484	116	198	327	278	262	79	107	157	142	256	683	518	553	1008	148	264	47
8	216	249	59	102	166	143	112	43	55	74	73	133	345	244	272	506	77	140	17
9	98	112	26	46	74	64	44	20	25	31	33	60	153	107	122	226	35	64	6
10	47	52	12	21	33	30	17	10	11	12	15	28	69	50	58	106	17	31	2
11	26	28	6	11	18	16	7	6	6	5	8	15	37	28	33	60	10	18	1
12	14	15	3	6	9	9	3	3	3	2	5	8	20	16	18	33	5	10	0
13	7	8	2	3	5	5	1	2	2	1	2	4	10	8	10	17	3	5	0
14	3	4	1	1	2	2	1	1	1	0	1	2	5	4	5	8	1	2	0
15	2	2	0	1	1	1	0	0	0	0	1	1	2	2	2	4	1	1	0
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	27027	35318	8716	14555	25554	19507	36412	4142	7706	9768	9078	17077	51456	67256	79459	62400	9274	10937	9854

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

OTHER Males

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Fishing year																		
1	8495	11403	2794	4750	8483	6159	7742	1156	2427	2002	2471	5132	15643	28146	30367	27675	2642	2511	3083
2	15158	20542	5059	8538	15328	11186	15326	2054	4269	4139	4529	9264	28049	46318	41491	51178	5371	4149	5975
3	7053	9402	2313	3899	6933	5131	8304	1002	2002	2361	2207	4341	13229	23941	14101	24748	2709	1851	2453
4	2761	3596	883	1488	2608	1958	3563	413	805	1123	907	1714	5313	11511	4353	9177	1115	820	696
5	1165	1450	352	599	1021	780	1534	188	355	529	396	720	2286	5386	1666	3395	498	446	193
6	533	607	143	252	403	317	682	96	171	248	183	319	1046	2273	745	1359	253	250	65
7	249	267	61	111	170	139	287	49	80	125	86	147	474	914	348	593	122	123	24
8	124	122	27	51	73	62	133	26	41	64	42	70	229	381	167	282	64	59	11
9	59	54	12	23	30	27	60	13	20	31	20	32	107	159	77	130	32	27	5
10	27	23	5	10	12	11	28	6	9	14	9	14	49	69	34	58	15	12	2
11	12	10	2	4	5	4	14	3	4	6	4	6	23	31	15	26	7	5	1
12	5	4	1	2	2	2	6	1	2	2	2	3	10	13	6	11	3	2	1
13	2	2	0	1	1	1	3	1	1	1	1	1	4	5	2	4	1	1	0
14	1	1	0	0	0	0	1	0	0	0	0	0	2	2	1	2	1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	35646	47484	11651	19728	35069	25775	37685	5009	10187	10647	10856	21765	66465	119150	93372	118638	12834	10256	12509

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

BAIT Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	366572	528073	206804	200358	235723	423277	263925	225843	167344	194123	206197	229216	256484	112657	201544	174059	117857	122034	100115
2	159596	224838	89065	84747	99729	180724	112870	96203	68007	84384	86458	95581	117617	39547	73604	70508	44731	49329	50637
3	25781	33655	13877	12385	14587	27323	17163	14425	9483	13194	13235	15673	16701	5966	10210	9976	6116	6779	7108
4	3900	4199	1928	1437	1697	3507	2238	1809	928	1923	1810	2520	1580	831	1192	1047	788	797	643
5	1045	991	491	319	378	846	546	429	161	524	492	687	259	202	269	203	209	186	84
6	362	337	169	108	127	289	187	146	48	186	181	235	77	65	91	64	75	63	18
7	129	120	60	38	45	103	66	52	16	67	68	83	26	22	33	22	27	22	4
8	46	43	21	14	16	37	24	18	6	24	25	29	9	7	12	8	9	7	1
9	16	15	7	5	6	13	8	6	2	8	9	10	3	2	4	2	3	2	0
10	5	5	2	2	2	4	3	2	1	3	3	3	1	1	1	1	1	1	0
11	2	2	1	0	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	557454	792279	312426	299413	352310	636123	397030	338935	245996	294436	308479	344039	392756	159301	286960	255890	169817	179221	158610

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

BAIT Males

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Fishing year																		
1	322511	461847	181419	174928	205815	370469	231097	197544	156490	170568	179225	205509	199435	103307	185683	146825	131866	144742	146080
2	45320	60072	24568	22217	26161	48670	30536	25738	18689	23813	22079	29163	26579	11654	22883	18360	17997	20299	21837
3	5263	5459	2562	1837	2171	4587	2937	2354	1165	2573	2265	3604	1873	1255	1962	1497	2241	2409	2231
4	1432	1348	671	432	512	1151	744	583	202	720	665	971	357	324	464	330	767	780	609
5	445	414	208	132	157	355	229	179	55	231	224	290	99	96	140	97	277	278	207
6	135	126	63	40	47	108	70	54	16	71	72	85	29	28	42	29	92	92	68
7	38	36	18	11	13	30	20	15	4	20	21	23	8	8	12	8	27	27	20
8	10	9	5	3	4	8	5	4	1	5	6	6	2	2	3	2	7	7	5
9	3	2	1	1	1	2	1	1	0	1	1	2	1	0	1	1	2	2	1
10	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	375157	529314	209514	199602	234881	425380	265639	226473	176621	198004	204557	239653	228383	116675	211189	167149	153278	168637	171059

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

RECREATIONAL Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	59524	55679	58896	98681	76845	65002	84641	42746	63301	62257	58708	71439	83057	47733	83647	65026	40884	47497	40407
2	196034	183370	203837	311431	299994	265114	323371	195526	277918	261621	260701	283657	366570	219692	359491	261797	172678	191739	179789
3	113951	106590	126286	170314	191264	178689	196890	135578	178249	165580	165312	167711	230320	146576	224744	157726	109162	128312	122393
4	39728	37161	48044	53861	72334	71558	69769	56529	64035	60097	57836	55936	80148	55622	80585	54628	38464	52377	48066
5	11845	11080	15776	14066	23280	23667	20838	19627	18840	18084	15926	15163	22274	17208	24114	15957	10617	18101	15361
6	3600	3367	5171	3756	7374	7701	6447	6667	5703	5442	4316	4123	6110	5274	7372	4951	2777	6111	4720
7	1670	1562	2299	1879	2312	2611	2166	2295	1928	1766	1197	1162	1710	1649	2370	1673	697	2069	1486
8	749	701	990	901	722	963	803	808	754	663	355	349	498	535	804	606	175	716	519
9	310	290	398	390	224	377	322	291	318	281	116	113	159	180	271	226	45	250	200
10	143	134	175	190	68	150	325	465	135	124	42	39	57	63	88	85	11	87	80
11	88	82	102	124	20	62	205	316	60	58	15	14	20	380	28	31	3	30	36
12	52	49	59	77	6	26	124	202	26	26	5	5	7	139	9	11	1	11	16
13	29	27	32	43	2	10	115	203	11	11	2	2	3	51	3	4	0	4	6
14	14	13	15	20	1	4	77	139	4	4	1	1	1	37	1	1	0	1	3
15	7	6	7	10	0	2	45	83	2	2	0	0	0	18	0	0	0	0	1
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	427744	400111	462088	655742	674446	615938	706138	461477	611284	576015	564532	599714	790934	495158	783528	562720	375513	447305	413084

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

RECREATIONAL Males

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	253144	236789	266438	397736	270645	200764	329205	153113	309824	305726	239273	336490	349025	144822	388881	349805	175254	197183	161516
2	310474	290417	355940	447748	436350	357265	562867	337758	512018	506183	492922	524612	628389	289487	673316	574785	315665	325205	312616
3	101691	95122	122699	138251	189950	175639	231085	162702	212421	203880	219365	192871	258945	137868	266899	227209	132453	139224	145203
4	28411	26575	35902	36396	62754	64360	70704	55599	67605	61405	68815	53248	77612	47216	81097	68334	40812	46974	49585
5	8604	8048	11280	10462	19763	22238	21864	18139	21410	18098	20046	14554	22251	15601	25539	20100	12132	15877	15988
6	2941	2751	4112	3225	6431	7724	8027	6321	7334	5961	6176	4417	6787	5505	9176	5999	3809	5615	5214
7	1173	1097	1718	1180	2122	2782	3401	2522	2657	2207	2257	1461	2356	1963	3770	1817	1322	2090	1814
8	501	469	748	484	704	1025	1623	1075	1085	949	940	572	958	731	1684	556	521	810	665
9	240	224	376	206	231	380	808	499	460	440	450	241	442	274	782	169	231	317	264
10	109	102	179	84	76	139	506	223	200	311	206	106	205	214	349	52	186	123	105
11	45	42	74	34	25	50	434	90	90	324	85	48	90	276	148	16	222	47	40
12	21	19	37	12	8	505	203	41	39	498	39	21	42	128	64	5	104	18	16
13	10	9	19	4	3	185	121	19	15	222	19	8	19	83	27	2	67	7	7
14	5	4	9	2	1	123	64	9	6	137	8	4	9	46	12	1	37	2	3
15	2	2	4	1	0	49	32	4	3	61	4	1	4	24	5	0	19	1	1
Unaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	707370	661671	799534	1035824	989063	833229	1230943	738113	1135167	1106403	1050604	1128654	1347134	644237	1451748	1248851	682835	733494	693038

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

SPECIAL RECREATIONAL LICENSE Females

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	2271	1621	1627	1975	1853	1734	1888	1756	1492	2715	1837	2228	2015	1594	2366	1156	730	1176	976
2	7307	6530	6867	8467	8629	7397	8396	6416	5950	10571	9822	9080	7950	7760	9629	5658	3813	5946	5544
3	4747	4839	5334	6326	6796	5730	6425	4399	4614	7019	8511	6064	5641	5997	6642	4523	3833	4862	4852
4	2024	2502	2794	3158	3586	3008	3161	2128	2496	3217	4598	2639	2793	2880	3045	2460	2709	2718	2850
5	758	1162	1315	1432	1801	1426	1387	995	1227	1430	2291	1105	1330	1167	1359	1220	1656	1383	1502
6	278	500	600	636	943	656	596	475	566	670	1062	486	621	454	641	595	923	647	768
7	121	227	301	312	501	331	300	288	366	421	587	272	335	183	334	281	533	346	440
8	54	100	143	147	241	158	145	154	205	227	281	140	169	75	162	125	269	170	219
9	25	43	66	67	114	72	67	76	104	112	125	67	81	30	75	52	127	79	101
10	15	21	33	36	58	38	42	54	115	111	79	49	54	14	46	20	91	37	55
11	15	16	24	29	35	31	46	68	200	170	91	65	64	11	51	8	155	19	47
12	7	7	11	13	15	14	22	32	94	80	44	30	30	5	23	3	67	10	22
13	4	4	6	7	7	8	12	19	59	51	26	18	17	3	13	1	37	5	12
14	3	2	3	4	4	5	8	12	40	34	16	12	11	2	8	0	25	2	7
15	1	1	2	2	2	2	4	7	22	19	9	6	6	1	5	0	13	1	4
Unaged	24	40	81	63	33	81	177	268	570	667	267	243	226	0	164	0	391	23	0
Total	17654	17613	19207	22677	24619	20692	22679	17147	18119	27515	29644	22503	21343	20176	24563	16102	15373	17422	17399

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

SPECIAL RECREATIONAL LICENSE Males

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	6344	3737	4423	5736	5710	4886	6101	5895	4077	11341	4729	7137	6053	4040	7497	5029	2285	4338	3005
2	9209	6514	8564	10530	9855	9318	11141	8162	7911	16462	11173	11133	10259	9805	13161	8400	4919	8703	6842
3	4026	3772	5085	5766	5939	5450	5851	4041	4404	7212	6753	5263	5157	6025	6489	4016	3671	5018	4589
4	1518	1871	2402	2625	2946	2591	2463	1775	2033	2777	2973	2116	2396	2693	2696	1802	2245	2481	2469
5	601	930	1099	1192	1399	1204	1054	793	1024	1136	1209	883	1144	1140	1174	829	1251	1190	1252
6	256	476	518	567	695	577	497	400	622	538	527	419	550	520	550	376	720	542	632
7	114	250	241	267	315	273	244	204	353	267	234	203	263	237	249	174	393	241	327
8	56	129	115	131	155	133	125	110	208	144	112	108	128	120	118	83	216	104	171
9	27	63	53	62	74	63	62	58	116	77	56	56	61	59	56	38	116	43	84
10	28	43	44	51	56	50	53	57	125	96	48	51	48	53	38	17	104	18	38
11	39	45	55	62	61	60	67	75	171	143	57	64	55	66	37	7	126	8	17
12	35	31	36	50	46	48	61	82	167	276	90	78	68	44	51	3	165	3	7
13	18	17	20	26	24	25	31	40	84	121	40	37	32	24	23	1	77	1	3
14	11	9	11	15	14	15	18	24	50	77	25	22	19	14	14	0	47	1	1
15	5	5	6	7	7	7	9	11	24	34	11	10	9	7	6	0	21	0	0
Unaged	68	71	120	125	79	146	299	464	1113	667	512	436	404	29	305	0	944	0	0
Total	22355	17963	22793	27212	27375	24845	28077	22192	22484	41369	28550	28017	26647	24875	32464	20776	17302	22690	19437

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

All gears combined Females

Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Fishing year																		
1	638801	731750	497707	619037	592863	718980	594633	468598	434550	534080	500955	636981	694998	344075	559587	418610	239958	311619	272363
2	1226499	932251	1214587	1683742	1672338	1432073	1528073	1182225	1195989	1501569	1454405	1741646	1857954	1076983	1633999	1137711	613041	930691	865164
3	740213	607038	760914	1029175	1140772	904925	966925	769896	751103	941675	1004909	1055755	1055674	731629	1058601	732735	424425	632272	601048
4	305016	331310	315212	399358	506107	398497	395173	323968	294364	382230	445145	408513	378367	316577	432181	316521	200976	276218	273059
5	112611	166928	116956	138453	194699	156969	143789	119499	99953	139352	172658	143456	126551	120601	157678	130029	88914	107656	111907
6	41280	73307	43555	49707	73442	60181	53048	44643	34134	52279	66346	53315	46853	45630	59523	56558	40396	42074	46735
7	17788	30740	19090	19823	28770	25088	21716	19767	14697	23248	28904	23590	22732	20517	26178	31922	22526	19354	22016
8	7612	11970	8133	8005	11245	10727	8987	9016	6544	10368	12638	10557	11047	9192	11352	16371	11502	8816	10057
9	3173	4507	3347	3196	4371	4609	3641	4092	2876	4507	5512	4698	5209	4043	4801	7815	5518	3931	4454
10	2322	2113	2064	1595	2035	2885	2581	3505	1859	3460	4270	3443	3608	3041	2886	6873	4554	2517	2522
11	3766	1497	2725	1097	1229	2650	2687	4045	2673	3819	4609	3922	3439	4545	2589	8454	5642	2377	1896
12	1714	694	1255	524	563	1283	1318	1993	1227	1880	2268	1874	1711	2091	1262	4148	2715	1165	922
13	1013	416	729	318	333	822	903	1358	692	1266	1533	1202	1100	1254	797	2758	1752	734	566
14	674	254	470	191	196	524	596	899	445	831	1006	785	694	830	500	1817	1151	461	342
15	370	138	255	103	105	289	335	505	239	465	564	436	382	456	274	1015	639	253	185
Unaged	8981	3628	5779	1471	1274	4221	4181	5937	3880	6851	8026	3435	6141	3395	3975	12945	14144	2976	630
Total	3111832	2898541	2992779	3955795	4230343	3724724	3728587	2959948	2845226	3607879	3713745	4093608	4216460	2684859	3956183	2886281	1677852	2343113	2213866

Table 2.2 (continued). Numbers of spiny lobster by age after settlement, gear, and fishing year.

All gears combined Males

	Fishing year																		
Age	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	1234426	1042846	1078891	1555491	1322950	1316818	1300647	996001	1251215	1507051	1040296	1394314	1661563	880242	1555434	1090018	581588	847153	726002
2	1423469	1079155	1435206	1960894	1934155	1538360	1986240	1401785	1721692	2043357	1702745	2089790	2319267	1357207	2306311	1589660	799250	1267681	1079179
3	582514	666722	610283	752986	911165	682400	894699	626839	686426	822142	835585	905626	909996	627690	975389	693030	369021	570539	518443
4	206153	372720	221749	248367	345728	260089	317985	226268	221046	285376	319496	315598	295315	237087	342847	259555	145073	210080	206141
5	75163	179678	82075	86727	127032	101389	115098	82590	74035	106342	120292	113224	102548	91660	126648	102571	59224	79557	82093
6	29020	77372	31909	32347	47645	42479	45896	33004	29273	44584	48971	44675	40777	40644	52829	46049	27381	32249	34348
7	11878	30798	12912	13164	18434	18383	19016	14397	12799	19947	21509	18949	17994	19773	23748	22804	13656	13947	15134
8	5099	11820	5469	5627	7442	8331	8285	6712	6347	9452	9966	8716	8650	10246	11456	11822	7101	6283	6969
9	2276	4484	2412	2423	3058	3857	3673	3240	3225	4591	4833	4065	4271	5396	5596	6185	3714	2868	3219
10	1390	2369	1356	1603	1532	2686	2254	2455	2259	3187	3373	2812	3065	3881	3274	4383	3205	1791	1599
11	1274	2088	1107	1703	1118	2794	2086	2723	2211	3204	3413	2911	3166	3871	2589	4347	3850	1675	984
12	1663	1990	1131	983	717	2881	2404	2928	2130	4221	4740	3302	4107	5762	2162	6341	5174	1927	1081
13	754	953	529	563	362	1393	1114	1415	1035	1930	2155	1553	1887	2576	1047	2843	2398	896	466
14	460	566	314	317	201	834	671	852	612	1178	1322	937	1151	1587	602	1749	1473	540	274
15	206	262	143	159	95	385	304	394	283	530	593	428	519	706	278	779	668	245	119
Unaged	6226	2382	5075	2428	758	2663	6412	13852	12130	8264	19746	8736	12782	10204	6003	13037	20752	6431	2639
Total	3581969	3476205	3490561	4665779	4722393	3985741	4706784	3415455	4026719	4865358	4139033	4915636	5387057	3298530	5416213	3855171	2043528	3043863	2678690

Table 2.3(1). Carapace lengths, number of lobsters that molted, mean growth increments, standard deviations of growth increments, and the number of molts per year for pre-recruit sized spiny lobsters.

CL (mm)	N	Mean Increment (mm)	St. dev.	Molts
47	5	6.20	1.10	5
48	8	6.88	2.90	5
49	6	7.93	3.09	4
50	5	7.76	4.00	4
51	16	6.28	1.68	4
52	8	6.10	1.16	4
53	13	6.31	1.52	4
54	15	6.30	1.58	4
55	15	6.19	1.94	4
56	18	6.99	2.65	4
57	17	6.84	2.66	4
58	16	6.59	1.67	4
59	18	6.47	2.54	4
60	29	6.86	1.76	4
61	22	7.07	2.37	4
62	21	6.60	2.12	4
63	40	6.55	2.14	4
64	19	7.12	2.40	4
65	35	6.10	2.23	3
66	35	6.55	1.88	3
67	39	7.58	1.84	3
68	29	6.86	2.06	3
69	35	6.76	1.77	3
70	39	6.62	2.05	3
71	29	6.38	2.16	3
72	37	6.22	1.81	3
73	40	6.44	2.67	3
74	38	6.37	2.76	3
75	41	6.80	2.56	3

Table 2.3(2). Tuning indices and the ages that they were applied to in the age-structured models used in assessment analyses. The Biscayne National Park creel survey, observer and adult monitoring pre-recruit, and puerulus indices were recalculated based on recommendations from the Data Workshop and the Stock Assessment Workshop.

	Fishery dependent						Fishery independent					
Fishing year	Legal-sized Observer Ages 3+ Number/trap	CV	Pre-recruit Observer Age 2 Number/trap	CV	Biscayne National Park Ages 2+ Number/trip	CV	Legal-sized Adult Monitoring Ages 3+ Number/dive	CV	Pre-recruit Adult Monitoring Age 2 Number/dive	CV	Puerulus Age 1 Number/collector	CV
1978-79					20.24	1.161						
1979-80					16.43	1.443						
1980-81					16.65	1.255						
1981-82					13.72	1.526						
1982-83					12.52	1.448						
1983-84					10.86	2.154						
1984-85					11.17	2.430						
1985-86					8.99	3.903						
1986-87					6.63	2.658						
1987-88					7.29	3.519					12.53	6.76
1988-89					7.43	3.509					13.41	6.85
1989-90					7.51	3.379					19.47	5.92
1990-91					6.76	2.409					13.59	7.12
1991-92					10.33	1.853					12.05	5.93
1992-93					7.84	3.298					12.46	7.99
1993-94	0.70	0.852	2.11	0.478	13.26	1.757					13.14	5.72
1994-95	1.14	0.920	2.24	0.636	10.13	1.947					14.36	6.12
1995-96	1.00	0.815	2.16	0.601	13.10	1.986					14.12	5.74
1996-97	1.08	0.930	2.60	0.604	11.01	1.689					8.57	6.77
1997-98	1.27	0.876	2.71	0.578	17.04	1.363	11.21	7.01	11.15	7.02	14.59	6.19
1998-99	1.08	0.964	3.15	0.601	13.53	1.634	11.45	6.72	4.91	10.12	18.20	5.31
1999-00	0.93	1.539	2.60	0.865	22.97	1.604	21.88	4.87	14.58	5.97	11.16	6.06
2000-01	0.86	1.162	2.31	0.725	12.69	1.559	23.05	4.96	11.01	7.13	13.31	5.84
2001-02					8.90	2.161	17.36	5.46	5.12	9.91	10.55	6.09
2002-03					12.98	1.926	14.32	5.82	6.26	8.69	11.42	6.18
2003-04					10.01	1.917	19.60	5.12	5.01	9.96	8.80	6.62
2004-05					12.30	1.812						

Table 3.1.1.2. Commercial and recreational landings (mt) by fishing year and the commercial catch rates and Biscayne National Park catch rates used in the surplus production model. The commercial catch rate was calculated only using trip tickets from Southeast Florida and the Florida Keys (Data Workshop Figure 3.1.1 (5)).

Fishing Year	Commercial	Bait	Recreational	SRL	Total	Commercial Kg / trip	Biscayne National Park Kg / trip
1978-79	2643.6	427.4	496.3	16.7	3584.1		21.2
1979-80	3582.1	428.5	640.2	21.4	4672.2		17.9
1980-81	2846.9	425.7	798.9	22.1	4093.6		18.0
1981-82	2622.0	360.9	692.8	21.5	3697.1		15.6
1982-83	2912.9	359.7	717.2	21.6	4011.4		13.7
1983-84	1972.6	380.4	535.7	18.0	2906.6		12.1
1984-85	2848.7	359.3	582.3	22.5	3812.8		14.0
1985-86	2698.9	439.6	564.5	19.9	3722.9	44.1	10.1
1986-87	2435.9	613.8	528.1	17.7	3595.4	48.3	8.7
1987-88	2462.2	666.7	627.5	20.9	3777.2	42.5	9.1
1988-89	3248.9	643.9	841.3	24.8	4758.9	54.3	10.0
1989-90	3555.8	748.7	827.3	25.8	5157.7	51.1	10.0
1990-91	2742.4	1353.8	720.7	22.6	4839.5	39.0	8.7
1991-92	3100.7	867.1	963.4	25.2	4956.5	41.9	12.1
1992-93	2434.8	733.9	613.4	20.1	3802.3	42.5	9.9
1993-94	2408.5	546.2	854.2	19.9	3828.7	46.8	15.9
1994-95	3257.5	635.5	830.6	31.5	4755.1	53.4	12.0
1995-96	3182.9	664.4	845.3	30.5	4723.1	52.1	15.1
1996-97	3512.6	763.2	847.3	24.8	5147.8	55.6	12.4
1997-98	3465.5	819.6	1022.5	23.0	5330.5	52.9	21.1
1998-99	2470.9	379.0	568.4	22.5	3440.8	47.8	15.8
1999-00	3478.7	687.7	1088.8	27.8	5283.0	56.5	27.3
2000-01	2525.9	600.1	870.7	17.7	4014.3	47.4	14.9
2001-02	1396.8	455.9	540.1	16.7	2409.4	40.1	9.4
2002-03	2076.3	476.3	607.7	20.5	3180.8	49.4	14.3
2003-04	1887.5	449.3	572.1	19.1	2927.9	49.7	11.7

Table 3.2.1.2. The landings, in numbers, and effort by sector and fishing year that were used in the DeLury model.

Fishing Season	Recreational Landings	Commercial Landings	Bait Landings	Total Landings	Recreational Person-days	Commercial Trips
1978-79	1032818	4712160	1489053	7234031	298427	32833
1979-80	1332146	6384958	1766902	9484006	384930	44488
1980-81	1653054	5074434	1450653	8178140	479513	35357
1981-82	1438200	4673563	1389579	7501342	416247	32564
1982-83	1487598	5192189	1440506	8120294	430799	36177
1983-84	1114641	3516013	1205460	5836114	322088	24498
1984-85	1218015	5077610	1458513	7754138	350689	35379
1985-86	1176734	4586067	932611	6695412	339625	32351
1986-87	1098768	3955795	1321591	6376154	317518	31082
1987-88	1305427	4657778	521939	6485144	377255	34407
1988-89	1743948	6381104	499015	8624067	505243	36431
1989-90	1718020	6650042	587191	8955253	497125	40276
1990-91	1496810	5154258	1061504	7712572	433092	40537
1991-92	1990623	5784865	662668	8438156	578003	45773
1992-93	1242648	4567343	565406	6375396	481276	35818
1993-94	1787054	4662274	422617	6871945	518641	31568
1994-95	1751298	6229495	492439	8473232	550898	32554
1995-96	1673330	5666412	513035	7852777	472707	32830
1996-97	1778889	6646664	583692	9009244	545809	32849
1997-98	2186058	6796320	621140	9603518	323006	34087
1998-99	1185036	4522375	275976	5983388	337574	26198
1999-00	2292304	6581944	498148	9372396	560140	28142
2000-01	1848447	4469964	423038	6741450	470467	26248
2001-02	1091022	2307262	323096	3721380	370026	19669
2002-03	1223197	3818081	347857	5389136	345777	24186
2003-04	1142960	3419929	329668	4892558	359214	22232

Table 3.2.2.1. Fit of DeLury model to harvests by sector and indices evaluated with correlation coefficients calculated on log-transformed values. The initial model run included all components and the final run only included those components with significant probabilities of the null hypothesis (Prob Ho) less than 0.05. The significance of the correlation coefficients were evaluated by calculating the corresponding Student-t (*t*) values for the specific degrees of freedom (df).

		Initial run				Final run			
Component		Correlations	df	t	Prob Ho	Correlations	df	t	Prob Ho
Recreational		0.74	10	3.44	0.006	0.81	10	4.35	0.001
Commercial		0.89	17	8.00	0.000	0.86	17	7.01	0.000
Bait		0.79	6	3.21	0.018	0.93	6	6.29	0.001
BNP cpue		0.82	24	7.13	0.000	0.79	24	6.41	0.000
Puerulus		0.61	13	2.75	0.017	0.77	13	4.36	0.001
FWC Diver	pre-recruit	0.85	5	3.63	0.015	0.96	5	7.54	0.001
FWC Diver	Legal-sized	-0.02	5	-0.06	0.958				
Observer	pre-recruit	0.29	6	0.75	0.483				
Observer	Legal-sized	0.45	6	1.23	0.265				

Table 3.2.2.9. Runs of the DeLury model with alternative natural mortality rates of 0.25 per year and 0.40 per year as well as the final run value of 0.34 for comparison.

	M = 0.25			M = 0.34			M = 0.40		
Fishing year	Population	Recruitment	Fishing mortality	Population	Recruitment	Fishing mortality	Population	Recruitment	Fishing mortality
1978-79	11483171	8904448	1.24	12490871	9626544	1.13	13179595	10154645	1.07
1979-80	14039017	11460294	1.67	15274707	12410385	1.52	16125090	13100145	1.44
1980-81	13916281	11864336	1.44	15152452	12783623	1.31	16007526	13451395	1.24
1981-82	12464193	9888319	1.31	13576164	10662884	1.19	14341018	11231397	1.13
1982-83	11768636	9143379	1.43	12809117	9872845	1.31	13523536	10409390	1.24
1983-84	10594219	8407976	0.99	11547590	9076572	0.90	12203541	9568068	0.85
1984-85	11088759	8020857	1.36	12031687	8693943	1.24	12678434	9191697	1.17
1985-86	9268602	7047701	1.25	10093722	7607855	1.14	10661542	8025002	1.08
1986-87	8014739	5953848	1.20	8740458	6446738	1.09	9230217	6804151	1.03
1987-88	8682835	6800744	1.34	9452109	7364622	1.22	9957335	7755753	1.16
1988-89	9989480	8224251	1.49	10891411	8911813	1.35	11406097	9308663	1.28
1989-90	9790584	8032692	1.61	10667514	8667736	1.46	11227370	9106118	1.38
1990-91	9313401	7783860	1.58	10137189	8379686	1.43	10710289	8825759	1.36
1991-92	12002602	10501606	1.83	12989837	11271554	1.67	13728844	11882069	1.58
1992-93	9441726	7947858	1.45	10284117	8544271	1.32	10883480	8989112	1.25
1993-94	10332599	8612638	1.34	11233221	9284490	1.22	11864878	9779541	1.15
1994-95	10881412	8771797	1.39	11834766	9473409	1.27	12471625	9963707	1.20
1995-96	11352335	9242682	1.35	12343279	9970037	1.23	13024570	10503433	1.16
1996-97	12125684	9836309	1.40	13188424	10622570	1.27	13903576	11179466	1.20
1997-98	13888462	11552512	1.30	15105763	12476357	1.18	15960591	13165356	1.12
1998-99	9146860	6196815	1.05	10007718	6715013	0.96	10583207	7091580	0.91
1999-00	13380675	10897109	1.25	14545604	11817742	1.14	15346224	12485699	1.08
2000-01	12583925	9609907	1.14	13711073	10407852	1.04	14525421	11035713	0.98
2001-02	9227528	6085047	0.86	10066814	6604308	0.79	10674246	7022016	0.74
2002-03	10879692	7848137	0.99	11808695	8544856	0.91	12477534	9077722	0.86
2003-04	9613931	6477678	0.94	10445244	7046259	0.86	11024769	7473836	0.81

Table 3.3.1.2(1) Catch-at-age by fishing years of both sexes and all gears.

	Age after settlement											
Fishing year	1	2	3	4	5	6	7	8	9	10	11	12+
1985	1873228	2649968	1322727	511169	187774	70300	29666	12710	5449	3713	5040	22059
1986	1774596	2011406	1273760	704031	346606	150679	61538	23790	8991	4482	3586	11283
1987	1576598	2649794	1371197	536961	199032	75464	32002	13602	5759	3420	3832	15680
1988	2174528	3644636	1782160	647725	225180	82054	32987	13632	5619	3198	2800	7056
1989	1915813	3606494	2051937	851835	321731	121087	47204	18687	7429	3567	2347	4605
1990	2035798	2970433	1587326	658586	258358	102660	43471	19058	8466	5571	5444	15295
1991	1895280	3514314	1861624	713158	258888	98944	40732	17272	7313	4836	4773	18239
1992	1464600	2584010	1396735	550236	202089	77648	34164	15728	7332	5960	6768	30134
1993	1685765	2917680	1437529	515410	173988	63407	27496	12891	6102	4118	4884	22673
1994	2041131	3544927	1763818	667606	245694	96863	43195	19821	9097	6647	7023	27416
1995	1541250	3157150	1840494	764641	292950	115317	50413	22603	10345	7642	8022	41952
1996	2031295	3831436	1961381	724110	256681	97990	42539	19273	8762	6255	6833	22689
1997	2356561	4177221	1965669	673682	229099	87630	40726	19697	9479	6673	6605	30474
1998	1224317	2434191	1359319	553664	212261	86274	40290	19438	9438	6921	8416	28860
1999	2115021	3940310	2033990	775028	284327	112351	49926	22808	10397	6159	5178	16900
2000	1508627	2727371	1425765	576076	232600	102607	54727	28193	14000	11256	12800	47430
2001	821546	1412291	793446	346049	148138	67777	36182	18603	9232	7759	9492	50865
2002	1158772	2198372	1202811	486298	187213	74322	33301	15100	6799	4307	4052	15629
2003	998364	1944343	1119491	479200	194000	81083	37151	17026	7673	4121	2880	7225

Table 3.3.1.2(2). Average weight (kg) of harvested spiny lobsters by age after settlement and fishing year.

	Age after settlement											
Fishing year	1	2	3	4	5	6	7	8	9	10	11	12+
1985	0.369	0.478	0.557	0.640	0.722	0.803	0.924	1.021	1.097	1.309	1.566	2.117
1986	0.338	0.484	0.625	0.730	0.795	0.839	0.887	0.937	0.986	1.181	1.463	2.005
1987	0.390	0.483	0.560	0.643	0.726	0.806	0.925	1.018	1.090	1.267	1.528	2.114
1988	0.396	0.479	0.547	0.625	0.711	0.796	0.897	0.978	1.039	1.245	1.497	1.966
1989	0.395	0.494	0.570	0.647	0.723	0.797	0.877	0.948	1.007	1.150	1.379	1.886
1990	0.367	0.482	0.566	0.652	0.739	0.828	0.931	1.022	1.099	1.308	1.527	1.911
1991	0.394	0.492	0.562	0.642	0.732	0.823	0.923	1.008	1.079	1.300	1.526	2.118
1992	0.388	0.490	0.562	0.640	0.728	0.828	0.958	1.058	1.134	1.360	1.558	2.448
1993	0.400	0.486	0.552	0.624	0.711	0.823	0.978	1.098	1.181	1.354	1.563	2.389
1994	0.403	0.484	0.556	0.642	0.736	0.841	0.968	1.066	1.142	1.349	1.548	2.117
1995	0.397	0.498	0.572	0.651	0.735	0.828	0.952	1.052	1.133	1.344	1.545	2.272
1996	0.400	0.487	0.554	0.634	0.728	0.831	0.952	1.047	1.114	1.321	1.542	2.234
1997	0.403	0.480	0.542	0.625	0.727	0.844	0.988	1.089	1.158	1.337	1.528	2.128
1998	0.403	0.495	0.568	0.651	0.743	0.857	1.002	1.112	1.194	1.378	1.577	2.098
1999	0.404	0.490	0.560	0.643	0.738	0.843	0.967	1.063	1.137	1.289	1.487	2.157
2000	0.400	0.489	0.566	0.662	0.769	0.884	1.029	1.118	1.179	1.362	1.551	2.058
2001	0.387	0.493	0.575	0.672	0.776	0.886	1.021	1.106	1.165	1.373	1.569	2.188
2002	0.401	0.495	0.568	0.652	0.743	0.833	0.951	1.041	1.107	1.286	1.502	2.075
2003	0.400	0.496	0.575	0.664	0.756	0.847	0.952	1.032	1.090	1.208	1.392	1.934

Table 3.3.1.3. Estimated average weight in the population from the length frequencies of diver-caught spiny lobsters.

	Age after settlement											
Fishing year	1	2	3	4	5	6	7	8	9	10	11	12+
1985	0.418	0.487	0.567	0.650	0.740	0.845	0.972	1.080	1.154	1.409	1.602	2.141
1986	0.427	0.502	0.597	0.702	0.802	0.893	0.989	1.064	1.116	1.302	1.531	2.137
1987	0.430	0.512	0.603	0.699	0.796	0.886	0.979	1.050	1.100	1.308	1.541	2.244
1988	0.432	0.506	0.593	0.692	0.791	0.887	0.983	1.059	1.114	1.324	1.550	2.205
1989	0.430	0.508	0.606	0.705	0.810	0.915	0.990	1.054	1.099	1.249	1.472	2.054
1990	0.431	0.510	0.603	0.702	0.800	0.892	0.986	1.058	1.110	1.312	1.542	2.251
1991	0.432	0.508	0.588	0.678	0.780	0.885	1.002	1.086	1.142	1.357	1.572	2.438
1992	0.418	0.492	0.586	0.690	0.804	0.923	1.051	1.129	1.177	1.388	1.585	2.491
1993	0.431	0.509	0.600	0.706	0.831	0.970	1.108	1.188	1.236	1.456	1.617	2.511
1994	0.426	0.489	0.574	0.673	0.784	0.911	1.059	1.144	1.197	1.442	1.613	2.222
1995	0.448	0.518	0.602	0.685	0.768	0.848	0.985	1.076	1.140	1.329	1.548	2.517
1996	0.428	0.493	0.572	0.667	0.777	0.900	1.033	1.122	1.180	1.384	1.582	2.503
1997	0.431	0.496	0.590	0.704	0.808	0.898	1.001	1.078	1.133	1.329	1.554	2.517
1998	0.447	0.520	0.596	0.676	0.766	0.873	0.969	1.066	1.138	1.395	1.599	1.881
1999	0.433	0.498	0.582	0.683	0.792	0.896	0.988	1.060	1.114	1.284	1.522	2.535
2000	0.436	0.501	0.593	0.703	0.797	0.872	0.931	0.983	1.024	1.061	1.095	1.133
2001	0.438	0.528	0.648	0.758	0.850	0.947	1.043	1.113	1.171	1.378	1.598	2.299
2002	0.441	0.514	0.611	0.719	0.809	0.873	0.964	1.028	1.074	1.119	1.183	1.682
2003	0.447	0.523	0.620	0.727	0.826	0.915	1.014	1.078	1.118	1.182	1.359	1.395

Table 3.3.2.1. Analysis of variances from components in the objective function for ICA.

Source	SSQ	Data	Parameters	d.f.	Variance
Catches at age	3.3466	121	41	80	0.0418
Aged Indices					
Observer pre-recruits	0.1265	8	1	7	0.0181
Observer legal sizes	0.2568	8	1	7	0.0367
FWC Adult Mon pre-recruits	0.7963	7	1	6	0.1327
FWC Adult Mon legal sizes	0.435	7	1	6	0.0725
Puerulus	0.4964	16	1	15	0.0331
Biscayne National Park	1.1754	19	1	18	0.0653
Total for model	6.6331	186	47	139	0.0477

Table 3.3.2.2. The parameters in the ICA model with their maximum likelihood values, CV, 95% confidence intervals, and the mean estimate.

Fishing mortality on age-3 spiny lobsters

Fishing year	Max Like	CV	Low 95%	Upper 95%	Mean
1993	0.40	9	0.34	0.48	0.41
1994	0.53	8	0.45	0.62	0.53
1995	0.56	8	0.48	0.66	0.56
1996	0.52	8	0.44	0.62	0.52
1997	0.53	8	0.44	0.63	0.53
1998	0.43	9	0.35	0.51	0.43
1999	0.52	9	0.43	0.63	0.53
2000	0.57	10	0.46	0.70	0.57
2001	0.33	12	0.26	0.42	0.33
2002	0.30	13	0.23	0.39	0.30
2003	0.26	15	0.19	0.35	0.26

Selectivity by age

Age	Max Like	CV	Low 95%	Upper 95%	Mean
1	0.26	9	0.22	0.32	0.26
2	0.89	9	0.75	1.07	0.90
3	1.00		Reference age		
4	0.90	8	0.76	1.06	0.90
5	0.72	8	0.61	0.84	0.72
6	0.57	8	0.49	0.67	0.58
7	0.51	8	0.44	0.60	0.51
8	0.44	8	0.38	0.52	0.44
9	0.37	8	0.32	0.44	0.37
10	0.46	8	0.39	0.55	0.46
11	1.00		Input		

Catchability coefficients for the tuning indices

Index	Max Like	CV	Low 95%	Upper 95%	Mean
Obs pre-recruit	3.31E-07	8	3.05E-07	4.27E-07	3.62E-07
Obs legal sizes	1.63E-06	8	1.50E-06	2.12E-06	1.79E-06
FWC pre-recruits	8.56E-07	9	7.78E-07	1.15E-06	9.49E-07
FWC legal sizes	2.02E-06	10	1.82E-06	2.78E-06	2.26E-06
Puerulus	1.00E-06	6	9.42E-07	1.21E-06	1.07E-06
BNP	6.61E-07	5	6.27E-07	7.80E-07	7.00E-07

Population at age 11

Fishing year	Max Like	CV	Low 95%	Upper 95%	Mean
1993	17139	23	10902	26945	17602
1994	18265	17	13002	25658	18542
1995	19707	15	14666	26480	19932
1996	19459	13	14807	25572	19649
1997	19460	13	15007	25235	19632
1998	21604	13	16742	27878	21788
1999	21898	12	17070	28092	22076
2000	24402	13	18902	31502	24610
2001	26115	14	19722	34581	26385
2002	27564	14	20675	36750	27863

Population in 2003-04 fishing year by age

Age	Max Like	CV	Low 95%	Upper 95%	Mean
1	15817033	17	11191283	22354768	16065347
2	9173617	12	7131197	11800998	9249664
3	5279875	12	4118579	6768615	5322445
4	2251366	13	1716418	2953037	2273037
5	1317076	14	988622	1754654	1331257
6	657987	15	484196	894157	666092
7	304364	16	222026	417238	308331
8	184414	16	134528	252799	186817
9	95169	15	69626	130081	96386
10	52435	15	38674	71094	53072
11	27949	15	20630	37866	28287

Table 3.3.2.3. Estimated number of lobsters at the beginning of the fishing year and age from Integrated Catch-at-Age.

	Age after settlement											
Fishing year	1	2	3	4	5	6	7	8	9	10	11	12+
1985	14301774	8680957	4151466	1844741	750043	326496	119847	58902	34059	14547	13669	59827
1986	16472586	8614184	3981192	1858667	888533	377728	173846	60634	31340	19694	7268	22867
1987	17719085	10240405	4457605	1778124	741333	346277	144520	72832	23519	14844	10287	42093
1988	17422213	11292310	5086414	2035770	820234	362306	183632	76221	40498	11951	7719	19453
1989	16087918	10582999	5017636	2145807	912180	396796	189580	103192	42882	24131	5849	11476
1990	16532535	9849186	4547154	1879197	824334	383097	182008	95685	57864	24324	14197	39887
1991	15906917	10065602	4546490	1923092	792648	372563	187387	93384	52224	34115	12677	48442
1992	16409537	9737525	4256477	1700845	779389	349715	182967	99459	52065	31062	20243	90129
1993	16891807	10453967	4783815	1872638	754711	386782	184272	101745	57662	30934	17141	79605
1994	18080203	10816731	5187756	2273899	927088	402248	218423	106752	60566	35328	18267	77825
1995	17957556	11210787	4809300	2180556	1007886	452448	211696	118844	60179	35451	19708	113374
1996	18894780	11033585	4831724	1952251	936696	479752	233406	113155	65970	34771	19460	65092
1997	16588775	11737800	4937108	2045459	870892	459482	253520	127459	63991	38716	19462	86601
1998	18867887	10288037	5222324	2076761	907244	425252	241921	137993	71877	37466	21606	97022
1999	17758641	12012712	5006057	2428323	1008004	475984	237139	138585	81347	43679	21900	48206
2000	13109367	11020856	5356715	2111092	1079511	493095	250973	129243	78238	47672	24403	127433
2001	14832186	8045620	4731560	2165086	903338	512256	253745	133853	71606	45133	26117	211043
2002	13934754	9680947	4261340	2419172	1144502	507284	301627	152568	82293	45075	27566	70934
2003	15817034	9173618	5279876	2251367	1317077	657988	304366	184415	95170	52437	27951	36992
2004	16398993	10517875	5177554	2898533	1268723	778296	403561	189765	117006	61512	33098	35652

Table 3.3.2.6. Estimated fishing mortality per year by fishing year and age from Integrated Catch-at-Age.

Fishing	Age after settlement										
year	1	2	3	4	5	6	7	8	9	10	11	12+
1985	0.17	0.44	0.46	0.39	0.35	0.29	0.34	0.29	0.21	0.35	0.56	0.56
1986	0.14	0.32	0.47	0.58	0.60	0.62	0.53	0.61	0.41	0.31	0.84	0.84
1987	0.11	0.36	0.44	0.43	0.38	0.29	0.30	0.25	0.34	0.31	0.57	0.57
1988	0.16	0.47	0.52	0.46	0.39	0.31	0.24	0.24	0.18	0.37	0.55	0.55
1989	0.15	0.50	0.64	0.62	0.53	0.44	0.34	0.24	0.23	0.19	0.63	0.63
1990	0.16	0.43	0.52	0.52	0.45	0.38	0.33	0.27	0.19	0.31	0.59	0.59
1991	0.15	0.52	0.64	0.56	0.48	0.37	0.29	0.24	0.18	0.18	0.57	0.57
1992	0.11	0.37	0.48	0.47	0.36	0.30	0.25	0.21	0.18	0.25	0.49	0.49
1993	0.11	0.36	0.40	0.36	0.29	0.23	0.21	0.18	0.15	0.19	0.40	0.40
1994	0.14	0.47	0.53	0.47	0.38	0.30	0.27	0.23	0.20	0.24	0.53	0.53
1995	0.15	0.50	0.56	0.50	0.40	0.32	0.29	0.25	0.21	0.26	0.56	0.56
1996	0.14	0.46	0.52	0.47	0.37	0.30	0.26	0.23	0.19	0.24	0.52	0.52
1997	0.14	0.47	0.53	0.47	0.38	0.30	0.27	0.23	0.20	0.24	0.53	0.53
1998	0.11	0.38	0.43	0.38	0.31	0.24	0.22	0.19	0.16	0.20	0.43	0.43
1999	0.14	0.47	0.52	0.47	0.38	0.30	0.27	0.23	0.19	0.24	0.52	0.52
2000	0.15	0.51	0.57	0.51	0.41	0.32	0.29	0.25	0.21	0.26	0.57	0.57
2001	0.09	0.30	0.33	0.30	0.24	0.19	0.17	0.15	0.12	0.15	0.33	0.33
2002	0.08	0.27	0.30	0.27	0.21	0.17	0.15	0.13	0.11	0.14	0.30	0.30
2003	0.07	0.23	0.26	0.23	0.19	0.15	0.13	0.11	0.10	0.12	0.26	0.26

Table 3.3.2.9. Comparison of total biomass, spawning biomass, recruitment, and fishing mortality per year on the fully recruited ages estimated with three natural mortality rates: 0.25, 0.34, and 0.40 per year.

	M = 0.25				M = 0.34				M = 0.40			
Fishing	Biomass (mt)		Recruitment	Fishing	Biomass (mt)		Recruitment	Fishing	Biomass (mt)		Recruitment	Fishing
year	Total	Spawning	Millions	mortality	Total	Spawning	Millions	mortality	Total	Spawning	Millions	mortality
1985	12030	2627	11.07	0.56	14980	3301	14.30	0.46	17959	4002	17.56	0.39
1986	13174	2604	12.87	0.57	16447	3342	16.47	0.47	19734	4116	20.02	0.39
1987	14579	3039	14.02	0.54	18064	3840	17.72	0.44	21533	4673	21.32	0.38
1988	15553	3168	13.83	0.62	19012	3962	17.42	0.52	22494	4794	21.01	0.45
1989	14999	2875	12.69	0.77	18355	3669	16.09	0.64	21791	4521	19.52	0.55
1990	14306	2884	13.00	0.63	17699	3688	16.53	0.52	21239	4563	20.18	0.44
1991	13945	2614	12.19	0.79	17443	3433	15.91	0.64	21167	4340	19.83	0.54
1992	13282	2830	12.55	0.60	16933	3743	16.41	0.48	20820	4754	20.42	0.39
1993	14586	3374	13.12	0.50	18465	4377	16.89	0.40	22563	5488	20.77	0.33
1994	15443	3175	14.14	0.65	19272	4129	18.08	0.53	23326	5199	22.15	0.44
1995	16145	3167	13.98	0.69	20167	4158	17.96	0.56	24472	5282	22.11	0.46
1996	15434	3065	14.65	0.65	19440	4048	18.89	0.52	23771	5171	23.38	0.42
1997	15225	3184	12.82	0.66	19204	4257	16.59	0.53	23549	5487	20.59	0.42
1998	15835	3427	14.63	0.54	20099	4522	18.87	0.43	24765	5781	23.39	0.34
1999	15990	3302	13.73	0.67	20152	4440	17.76	0.52	24749	5751	22.11	0.42
2000	13947	2983	9.89	0.74	17851	4196	13.11	0.57	22191	5583	16.60	0.44
2001	13444	3645	11.08	0.44	17791	5030	14.83	0.33	22562	6579	18.85	0.26
2002	13484	3842	10.52	0.39	17571	5121	13.93	0.30	21969	6520	17.52	0.24
2003	15079	4497	12.17	0.33	19234	5719	15.82	0.26	23636	7050	19.60	0.21

Table 6.2 Age specific natural mortality rates, selectivities, average female weight, proportion mature, number of broods per spawning season, and average number of eggs produced per spawn.

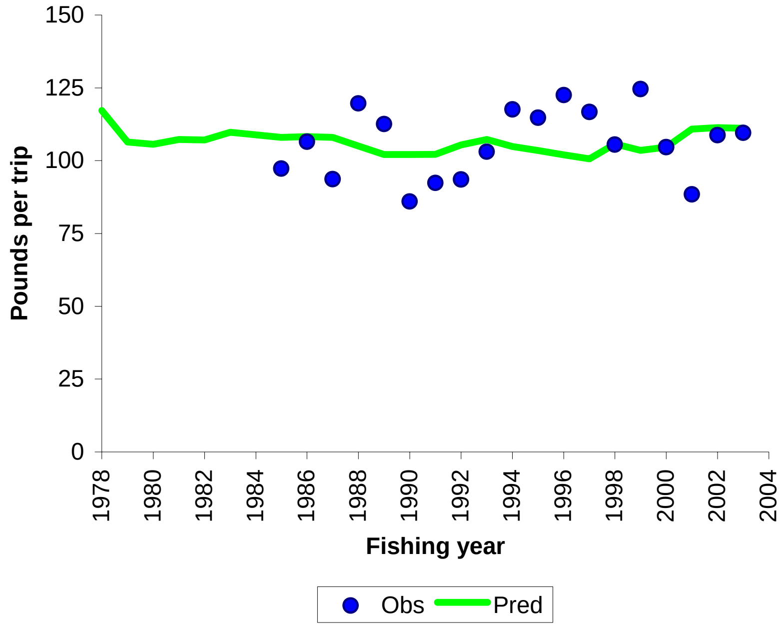
Age	M	Selectivity	Weight (kg)	Prop. Mature	Broods	Eggs
1	0.34	0.262	0.430	0.00	0	381199
2	0.34	0.893	0.484	0.50	1	434679
3	0.34	1.000	0.558	0.75	1	501219
4	0.34	0.899	0.659	1.00	2	587077
5	0.34	0.717	0.754	1.00	2	665787
6	0.34	0.573	0.827	1.00	2	725157
7	0.34	0.510	0.925	1.00	2	801854
8	0.34	0.443	0.983	1.00	2	845363
9	0.34	0.371	1.021	1.00	2	873452
10	0.34	0.463	1.144	1.00	2	946934
11	0.34	1.000	1.457	1.00	2	1080890
12	0.34	1.000	1.451	1.00	2	1087491
13	0.34	1.000	1.461	1.00	2	1096796
14	0.34	1.000	1.507	1.00	2	1117078
15+	0.34	1.000	2.224	1.00	2	1125765

Table 6.3. Fishing mortality rates on fully recruited spiny lobsters (Age-3), static SPR values based on eggs per recruit, and combined landings across sectors and gears in number and weight in metric tons by fishing year.

Fishing year	Fishing mortality yr-1	Static SPR eggs	Landings Numbers	Landings mt
1985	0.46	22%	6693801	3319.561
1986	0.47	22%	6374746	3404.158
1987	0.44	23%	6483341	3306.857
1988	0.52	19%	8621574	4282.478
1989	0.64	14%	8952736	4669.337
1990	0.52	19%	7710465	3896.726
1991	0.64	14%	8435371	4365.521
1992	0.48	21%	6375403	3333.012
1993	0.40	26%	6871945	3498.349
1994	0.53	18%	8473237	4359.056
1995	0.56	17%	7852778	4247.498
1996	0.52	19%	9009244	4632.255
1997	0.53	18%	9603517	4837.133
1998	0.43	24%	5983389	3219.949
1999	0.52	18%	9372396	4863.403
2000	0.57	17%	6741452	3633.200
2001	0.33	32%	3721380	2083.101
2002	0.30	35%	5386976	2851.764
2003	0.26	40%	4892556	2626.228

Figure 2. Geographic regions for spiny lobster.

a. Commercial pounds per trip



b. Biscayne National Park Creel Survey

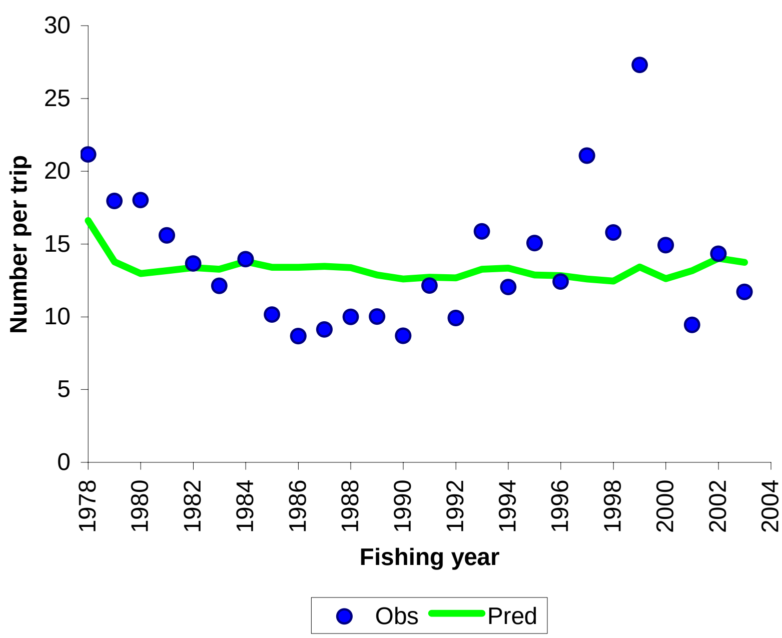


Figure 3.1.2. Fits of surplus production model to standardized commercial pounds per trip (a) and to Biscayne National Park Creel Survey (b).

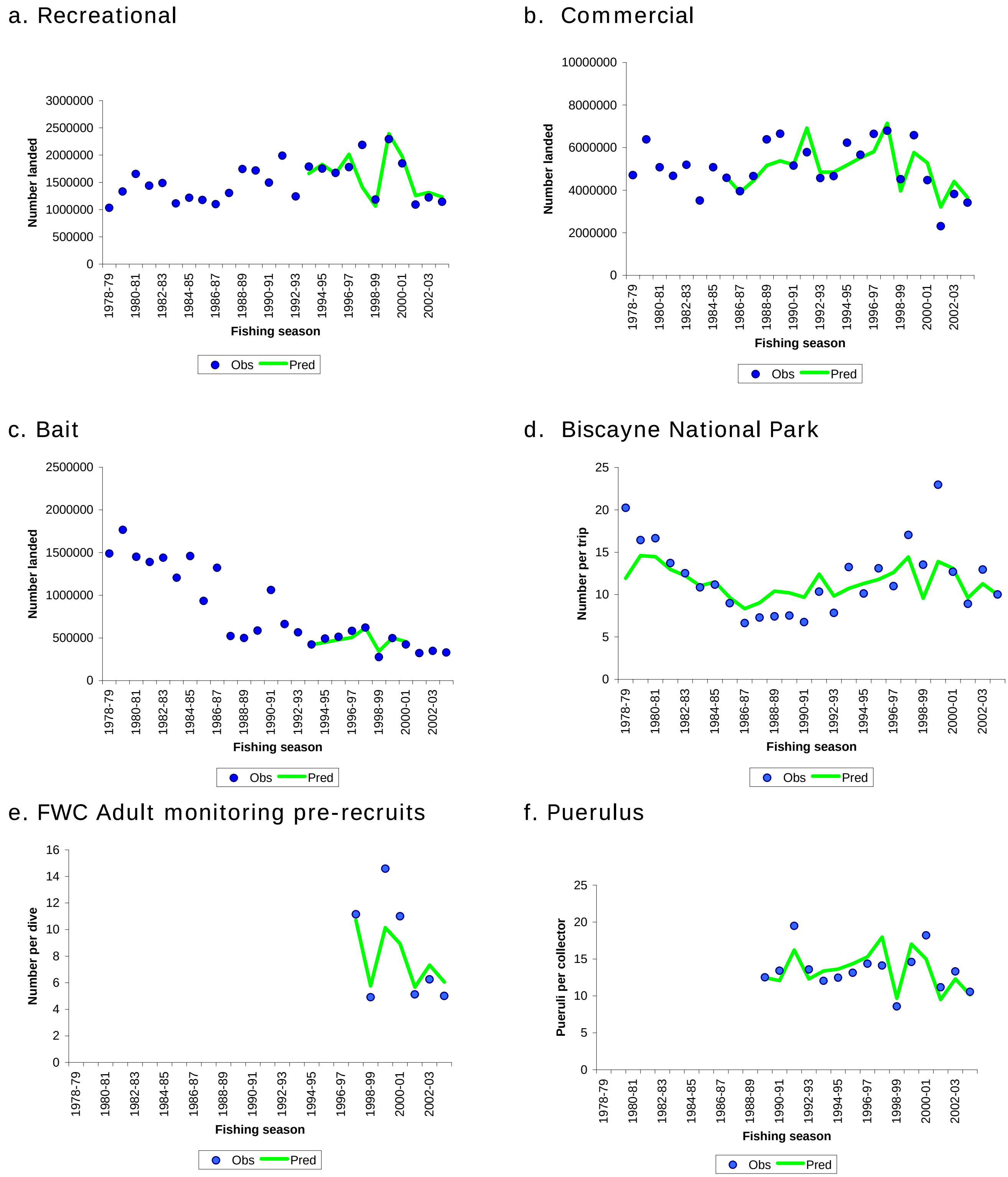
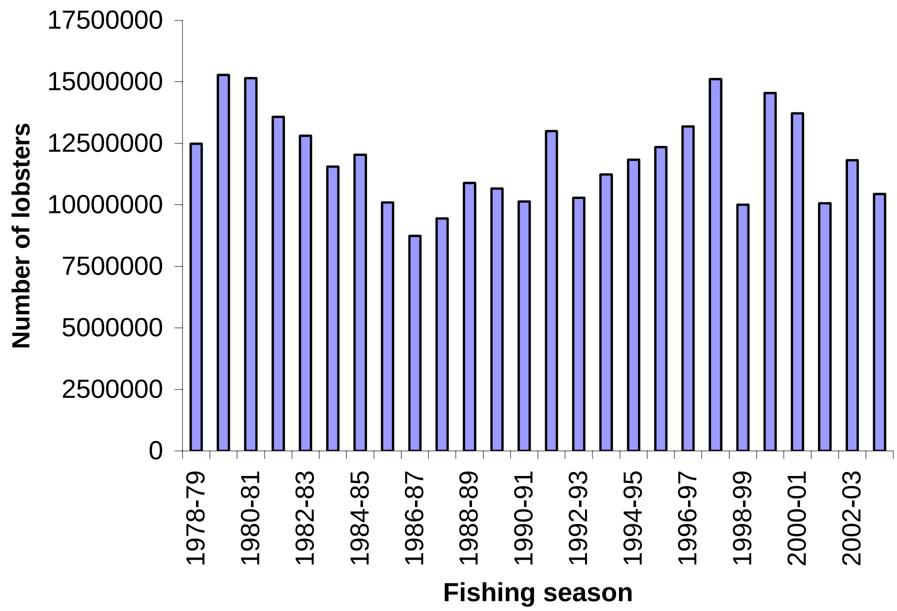


Figure 3.2.2.1. Fit of DeLury model final run to harvests by sector and indices a) recreational, b) commercial, c) bait, d) Biscayne National Park, e) FWC pre-recruits, and f) puerulus offset by two years.

a. Population size



b. Recruitment

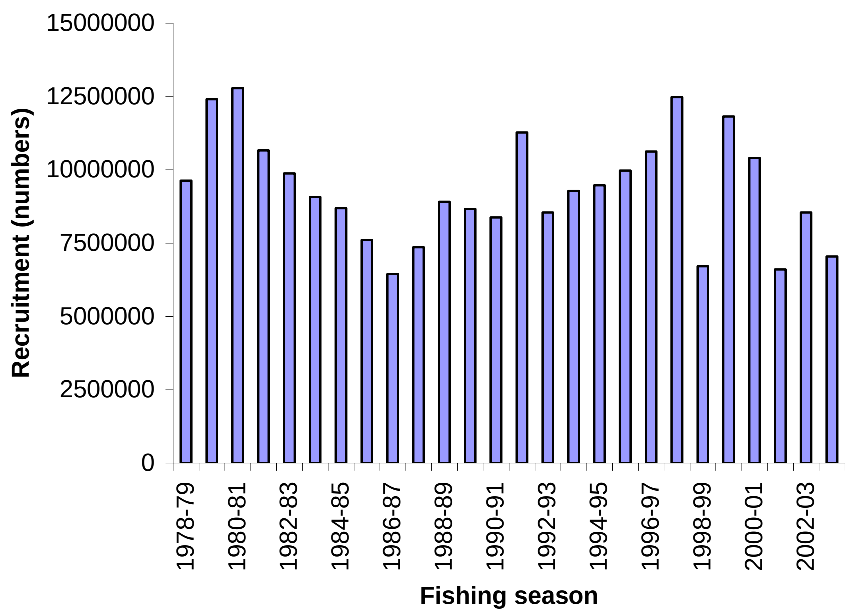


Figure 3.2.2.3. Estimated number of fish at the beginning of the year (a) and recruitment (b) by fishing year.

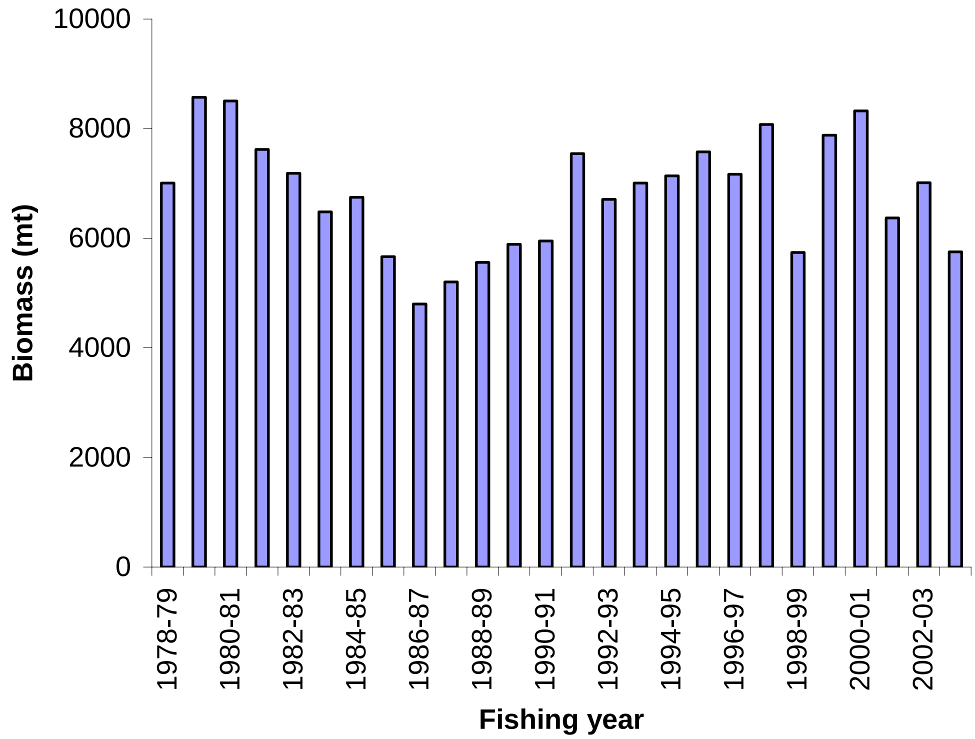


Figure 3.2.2.4. Biomass by fishing year.

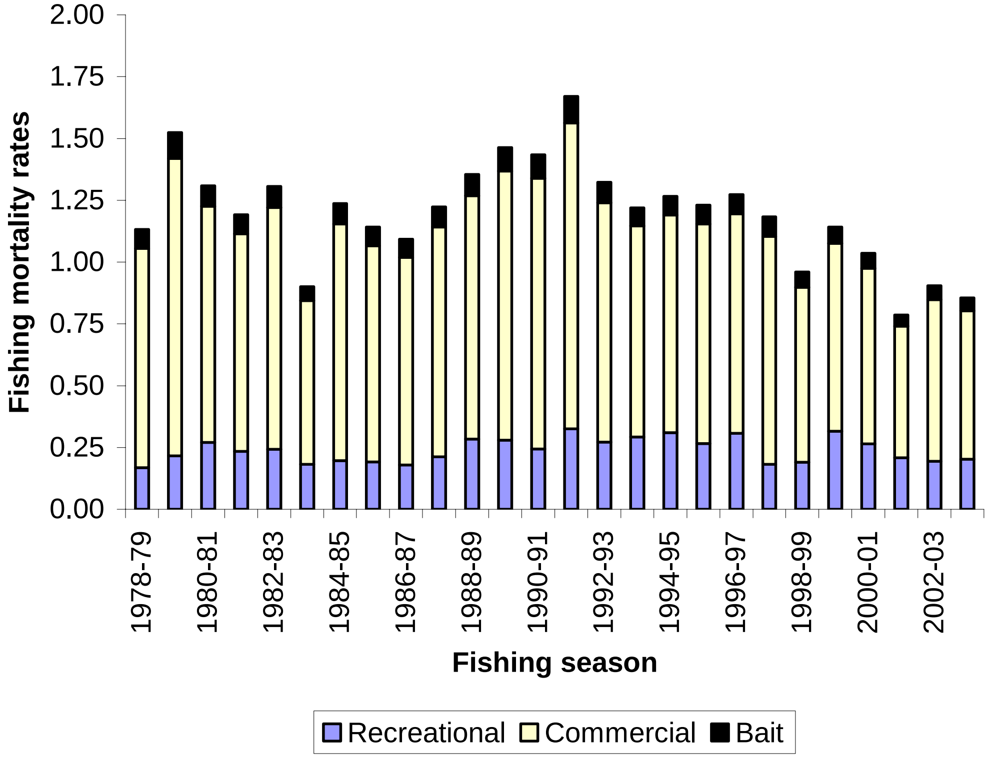


Figure 3.2.2.6. Fishing mortality per year by fishing year for the recreational fishery (black bars), commercial fishery (light bars), and bait fishery (medium bars).

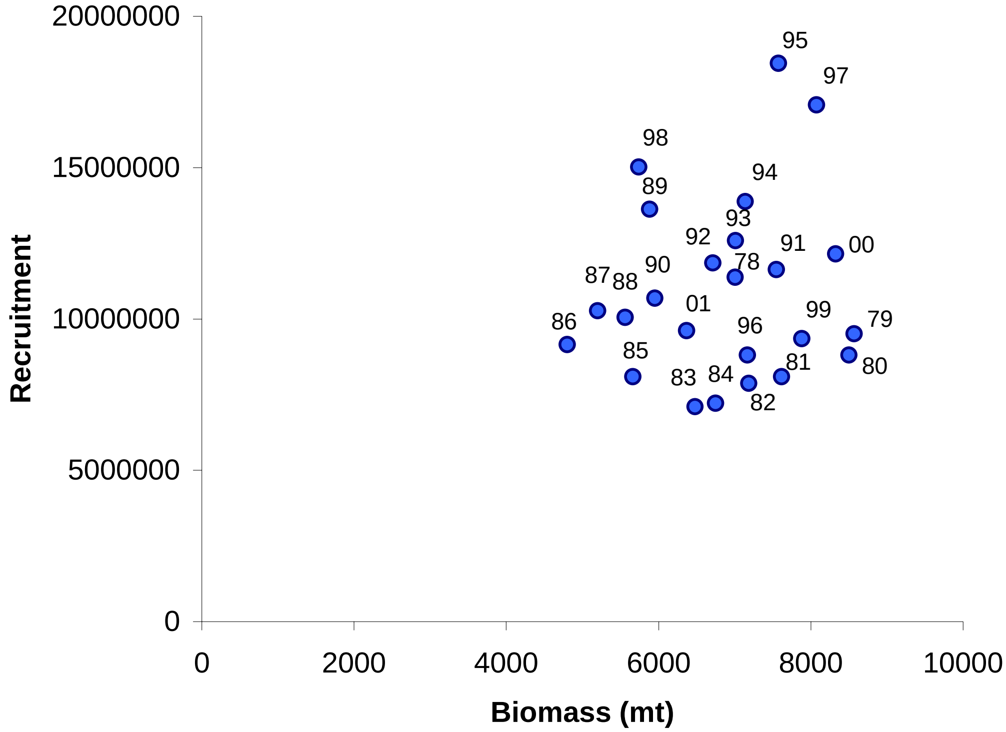
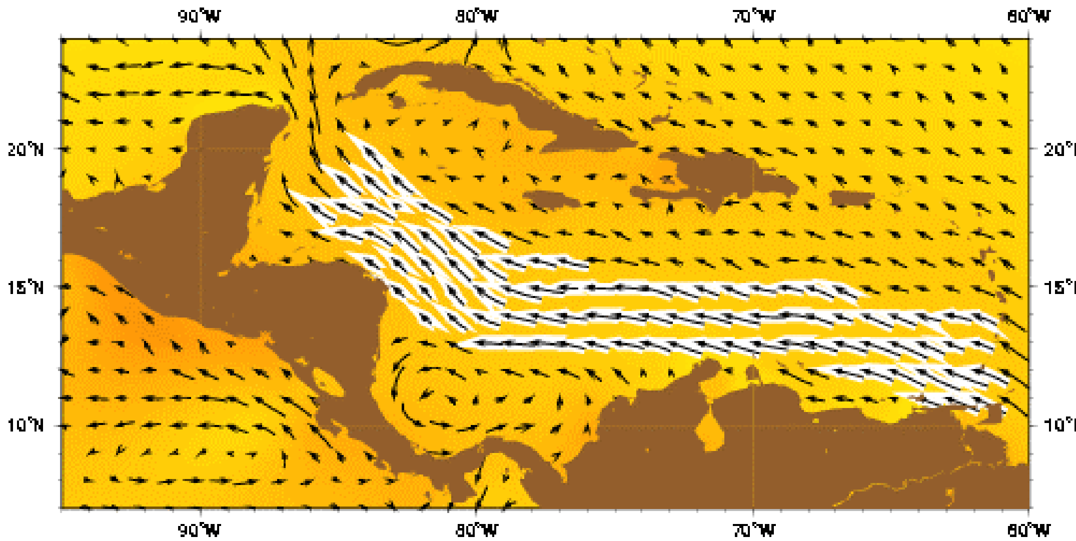


Figure 3.2.2.7(1). Stock in biomass and recruitment two years later. The numbers above the points are the biomass years (78-01).

a. Caribbean Current



b. Loop Current

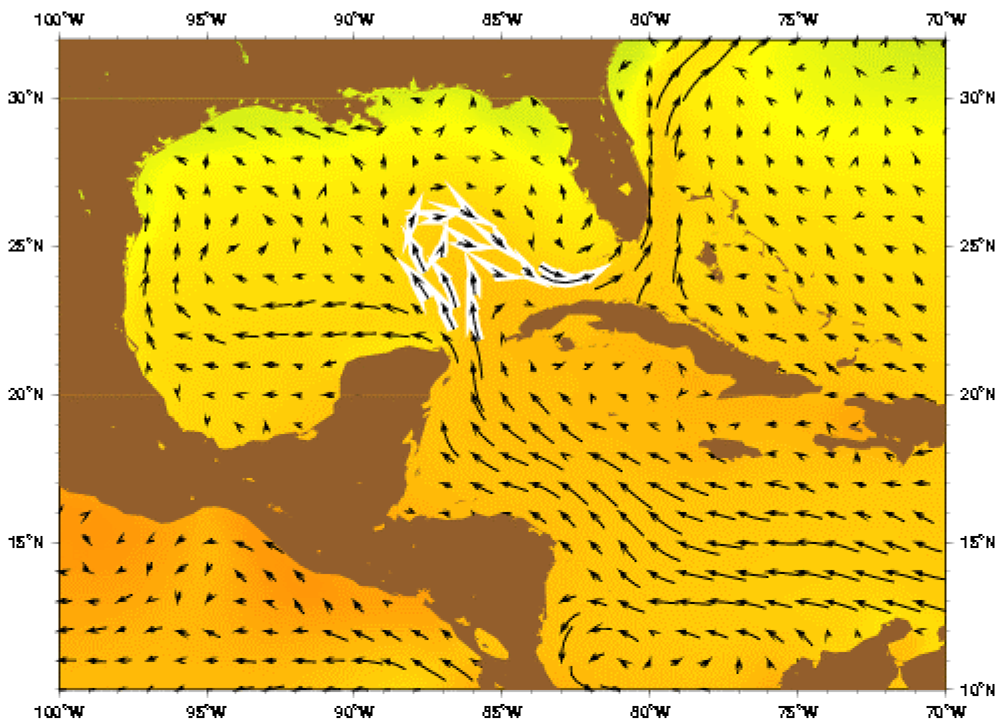
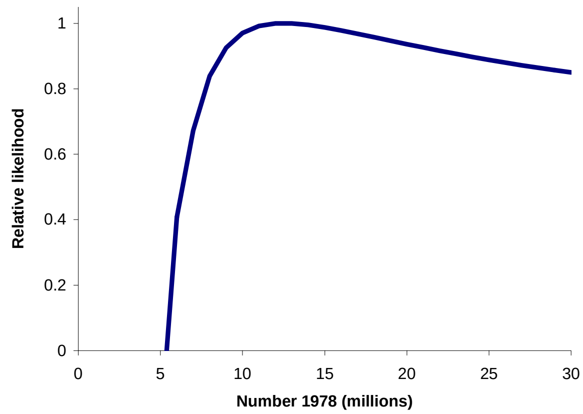
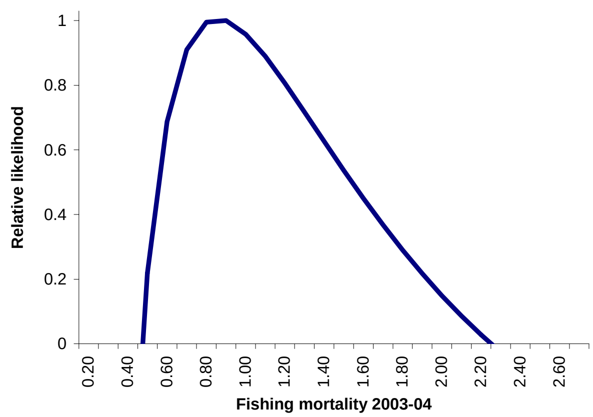


Figure 3.2.2.7(2). The Caribbean Current (a, Gyory et al. undated a) and the Loop Current b, Gyory et al. undated b).

a. Initial population size



b. Fishing mortality rate in 2003-04



c. Biomass in 2003-04

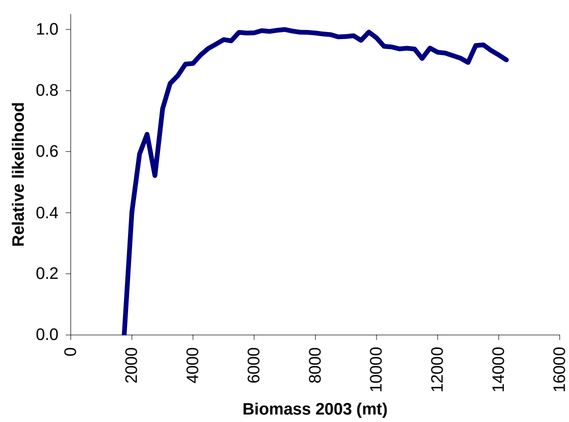
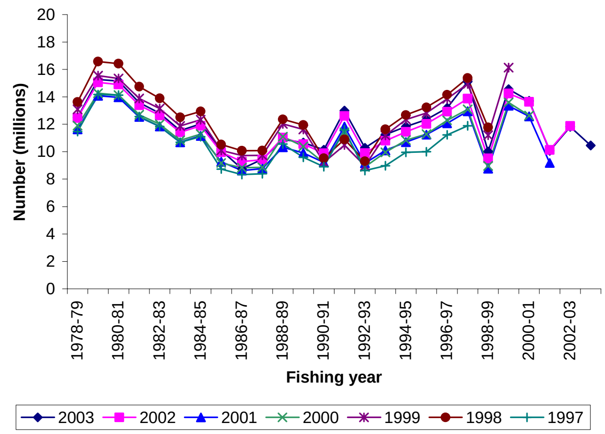
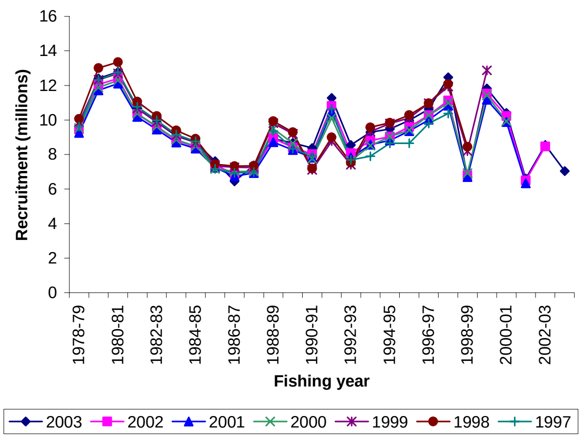


Figure 3.2.2.8 Likelihood profiles for the DeLury model.

a. Initial population size



b. Recruitment



c. Fishing mortality rates

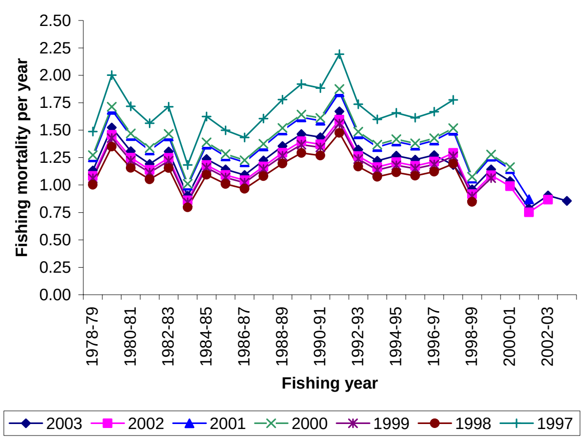


Figure 3.2.2.9. Retrospectitve analyses of the DeLury model with ending fishing years 1999-00 through 2003-04.

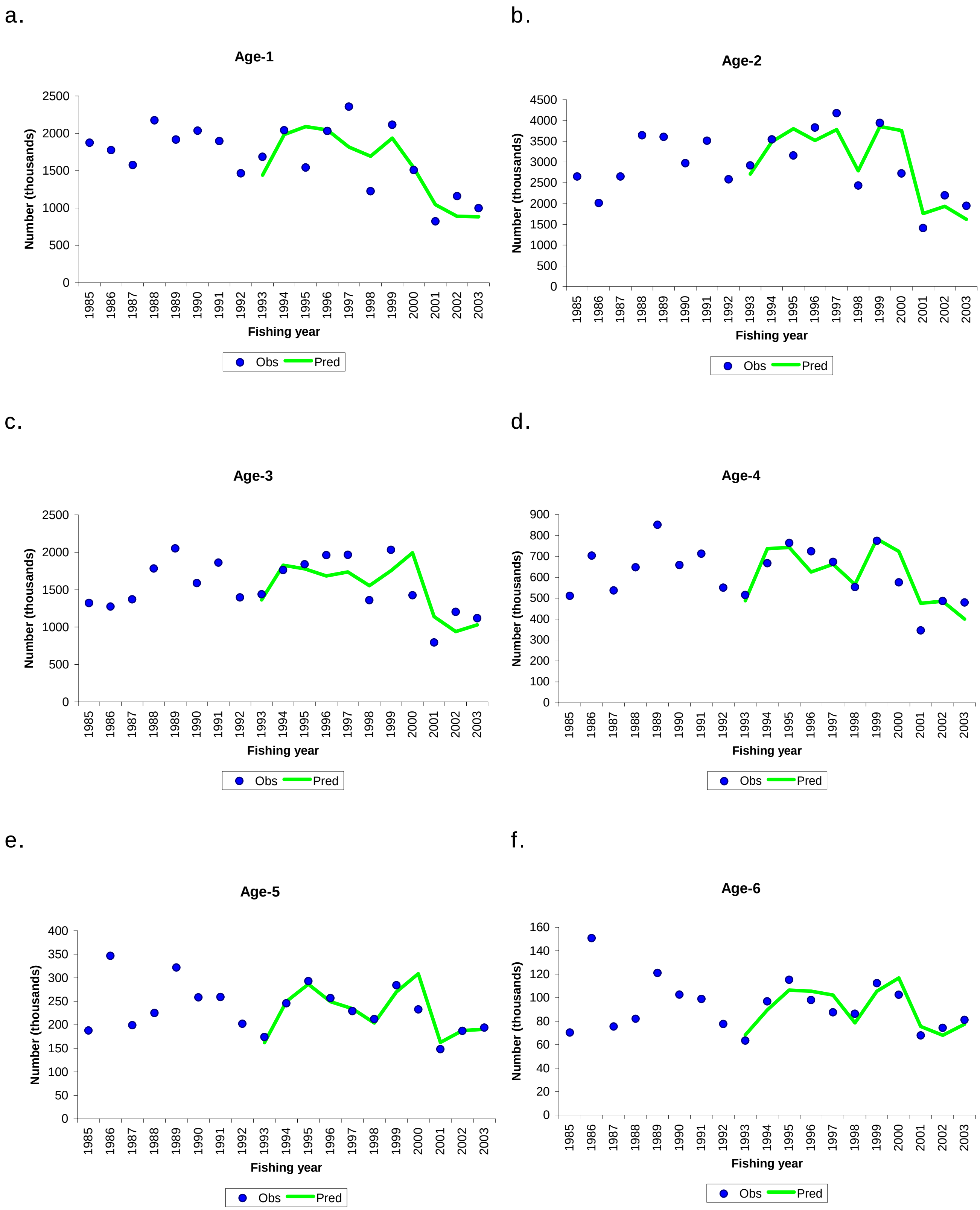


Figure 3.3.2.1(1). Fits of the catches-at-age in the ICA model.

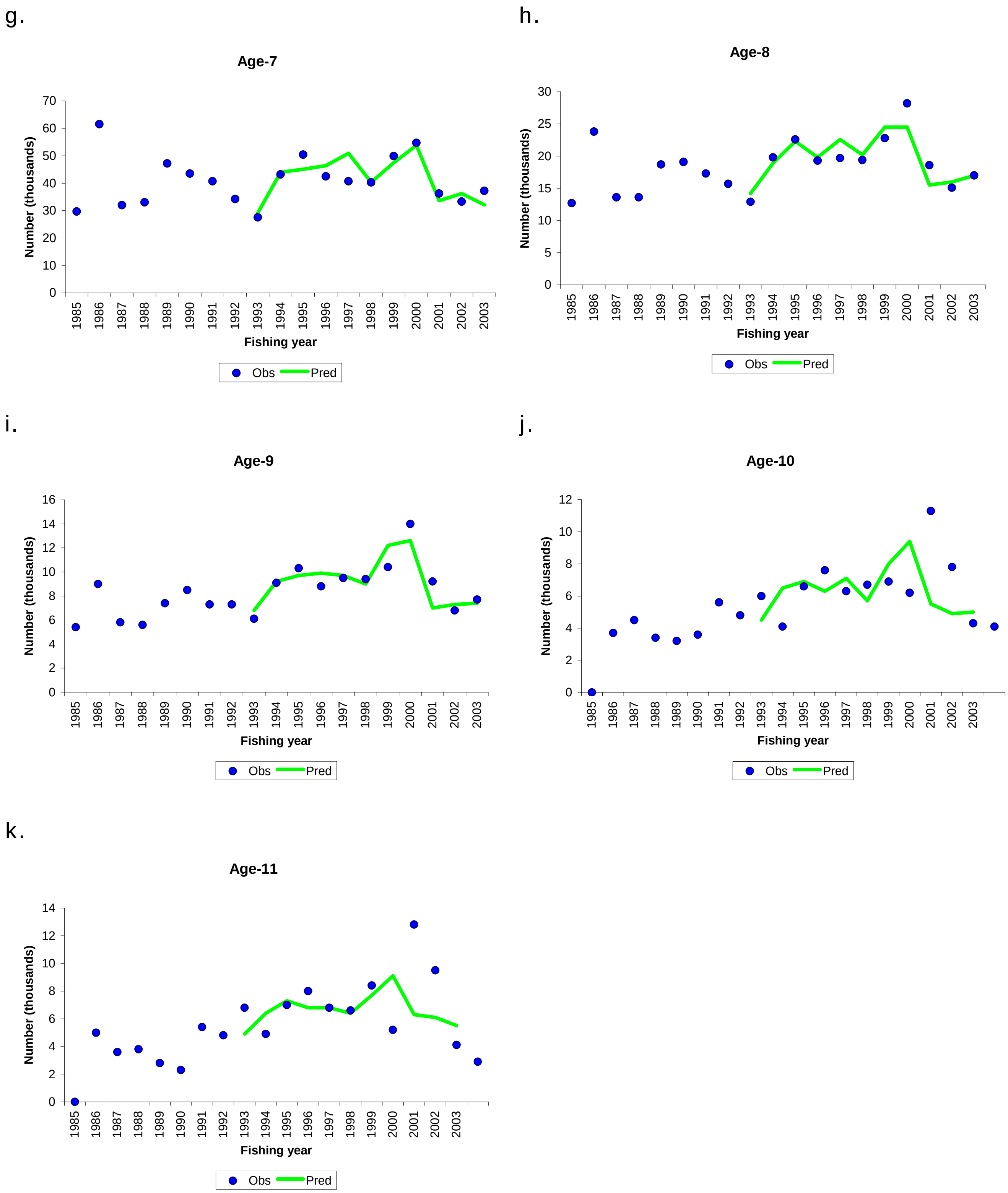


Figure 3.3.2.1(1) Continued. Fits of the catches-at-age in the ICA model.

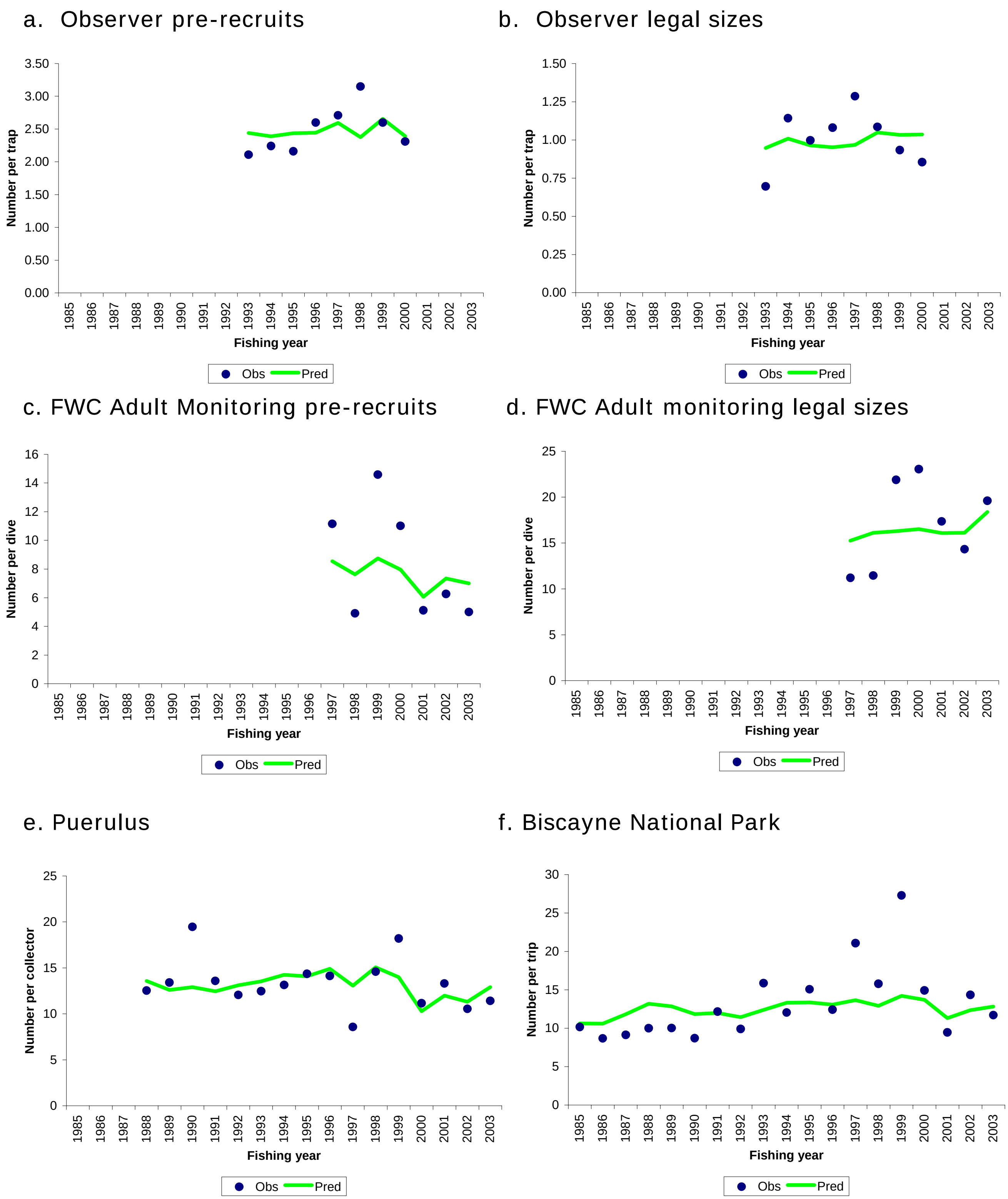
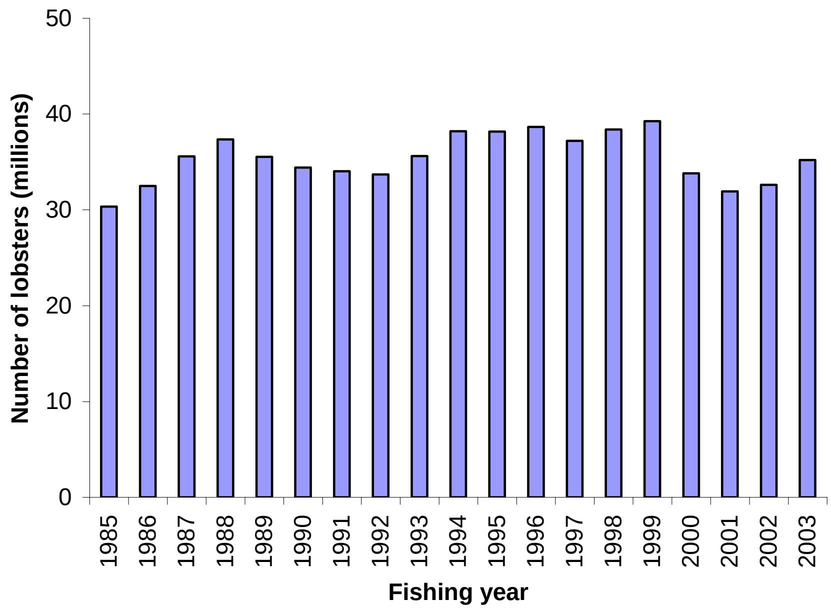


Figure 3.3.2.1(2). Fits of the tuning indices to ICA.

a. Population



b. Recruitment of Age-1 lobsters

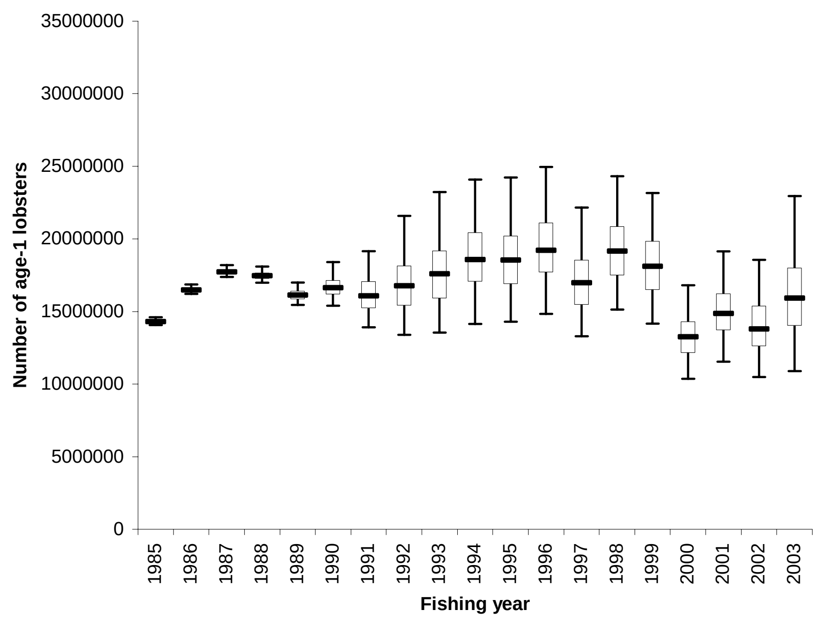
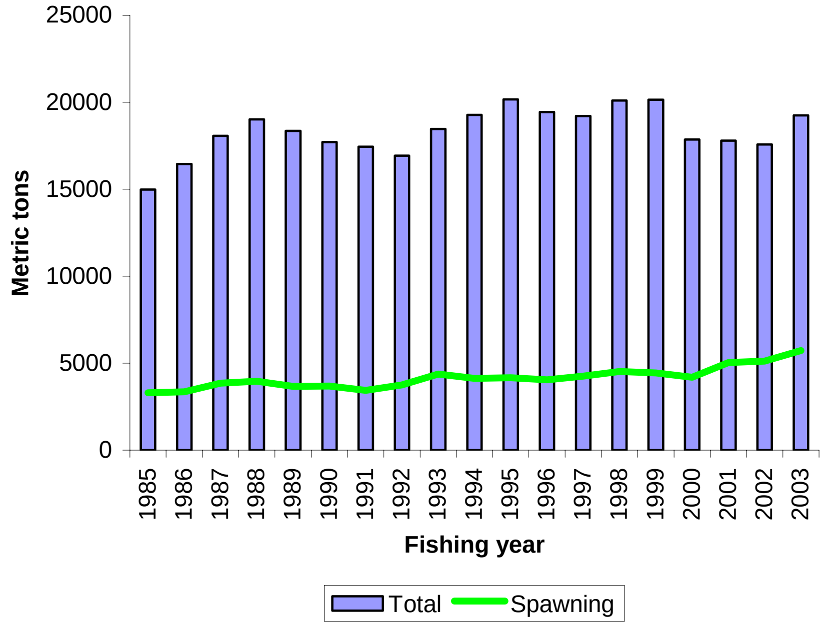


Figure 3.3.2.3. The total number of lobsters by fishing year (a) and the number of age-1 recruits based on 1000 Monte Carlo runs using the covariance matrix (b). The vertical line is the 95% confidence interval, the box is the inter-quartiles (25 to 75 percentiles) and the horizontal line is the median.

a. Total biomass



b. Spawning biomass in Florida

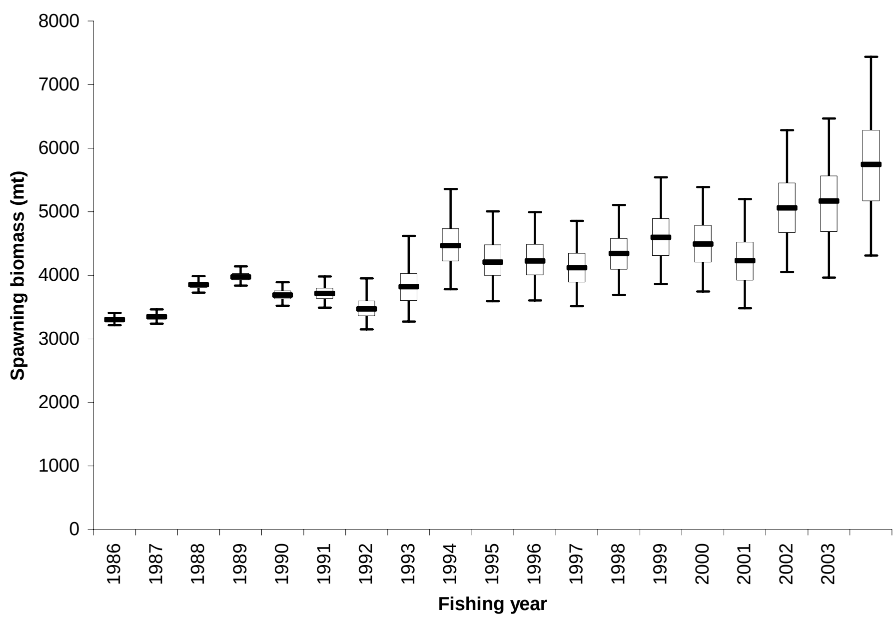


Figure 3.3.2.4. Total biomass and spawning biomass in Florida by fishing year. The vertical line is the 95% confidence interval, the box is the inter-quartiles (25 to 75 percentiles) and the horizontal line is the median.

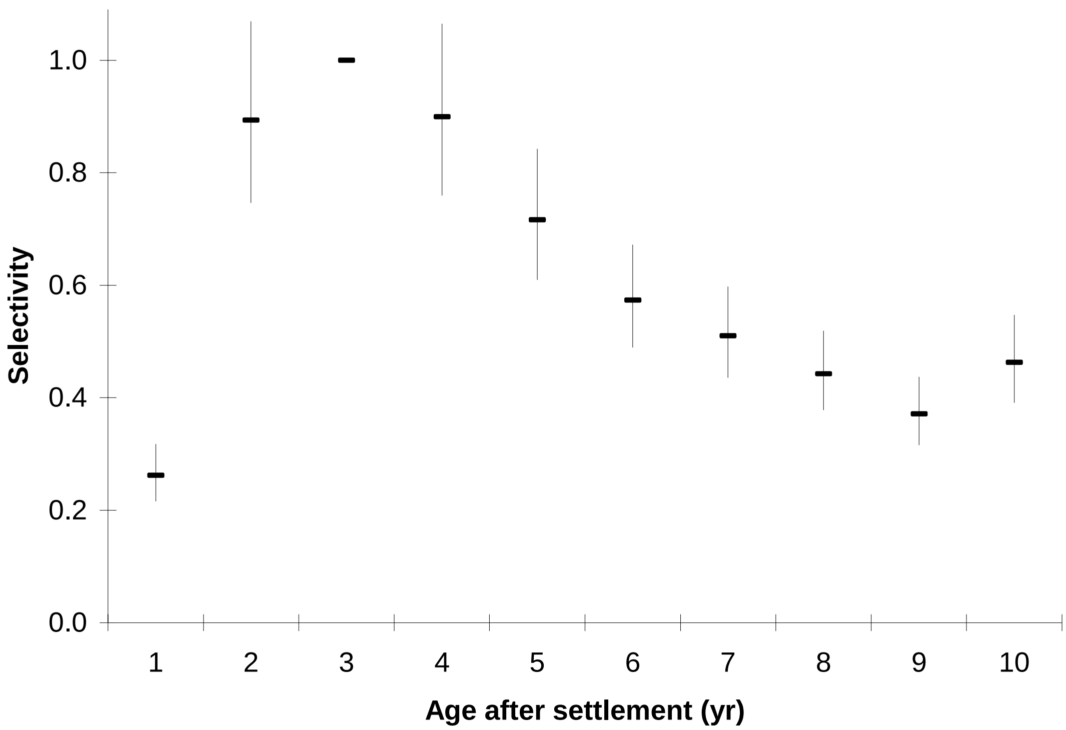
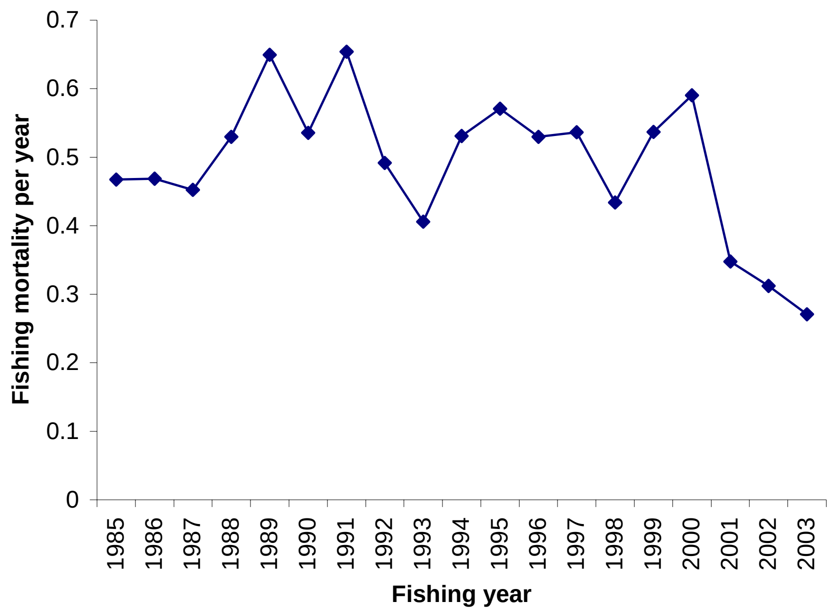


Figure 3.3.2.5. Selectivity by age for the period 1993-94 and later. The vertical lines are the 95% confidence intervals and the horizontal line is the maximum likelihood point estimate.

a. Fishing mortality per year on age-3 lobsters



b. Average fishing mortality on ages 1-5

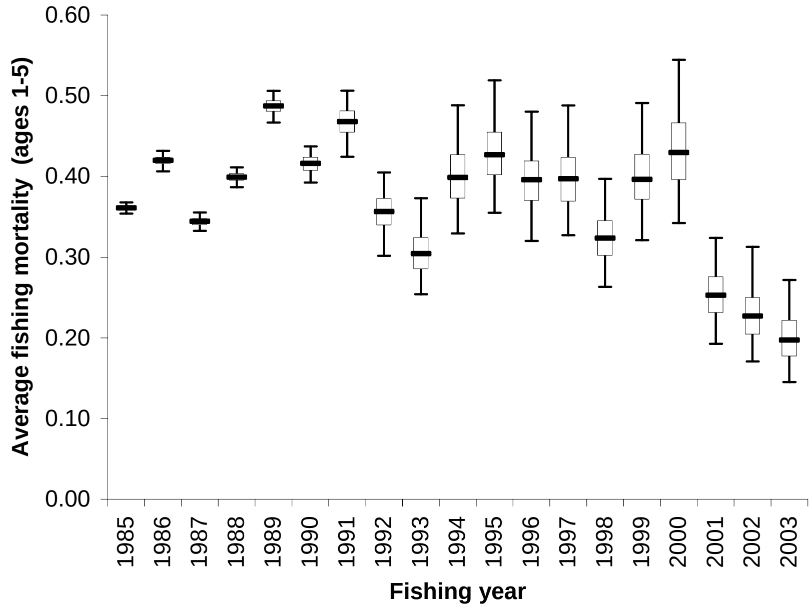


Figure 3.3.2.6. Fishing mortality rates estimated by ICA. The uncertainty in the average fishing mortality rates is based on 1000 Monte Carlo runs using the covariance matrix. The vertical line is the 95% confidence interval, the box is the inter-quartiles (25 to 75 percentiles) and the horizontal line is the median.

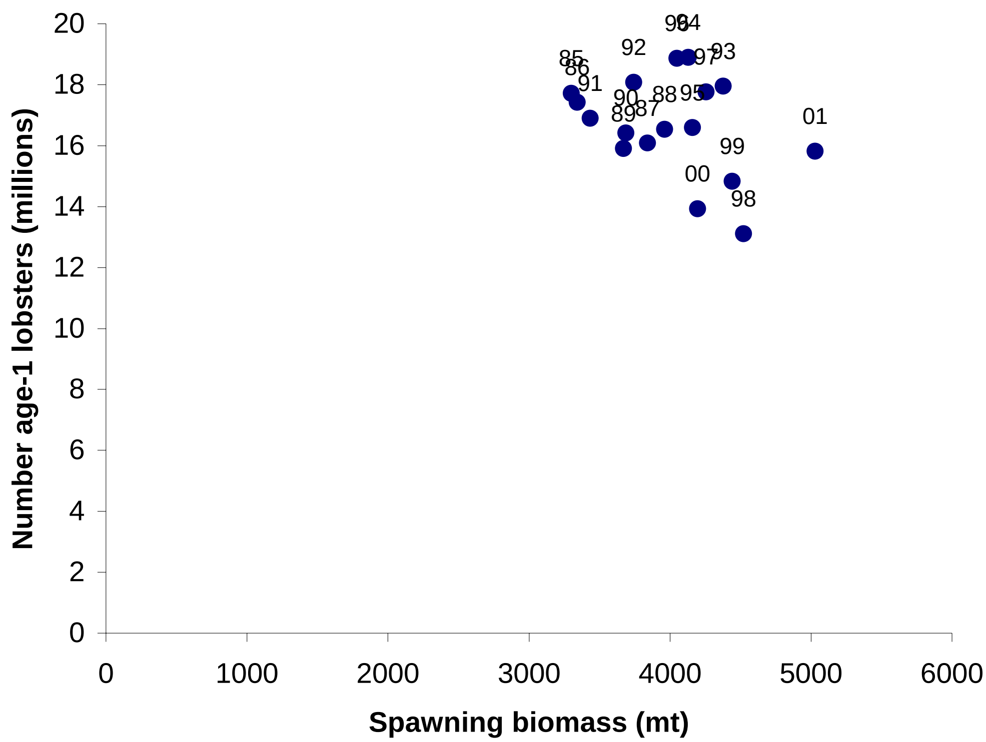
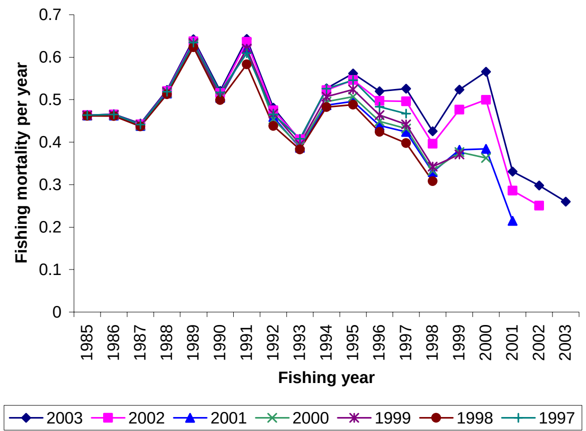
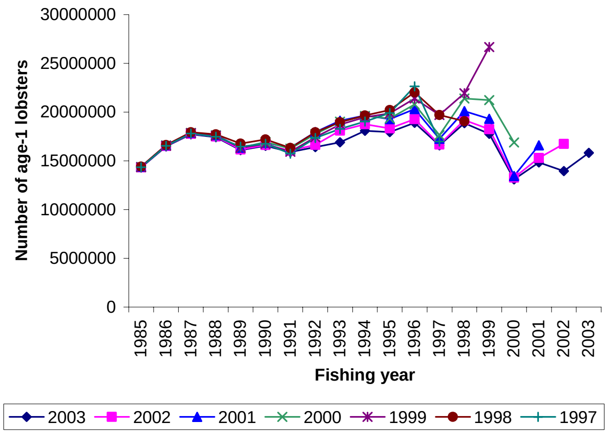


Figure 3.3.2.7. Spawning biomass and the number of age-1 lobsters two years later. Ages are the time after settlement which occurs when lobsters are about nine months old so that an age-1 lobster actually is almost two years old.

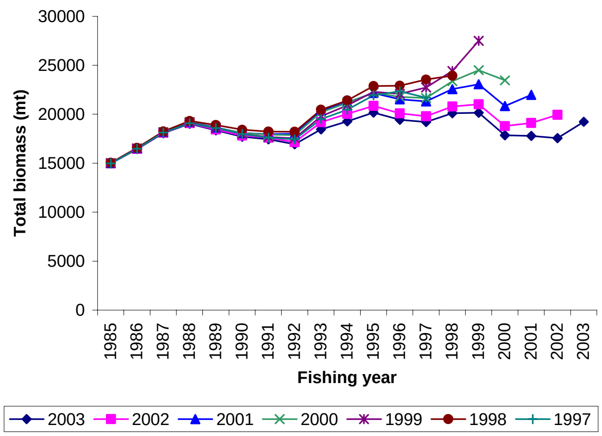
a. Fishing mortality per year



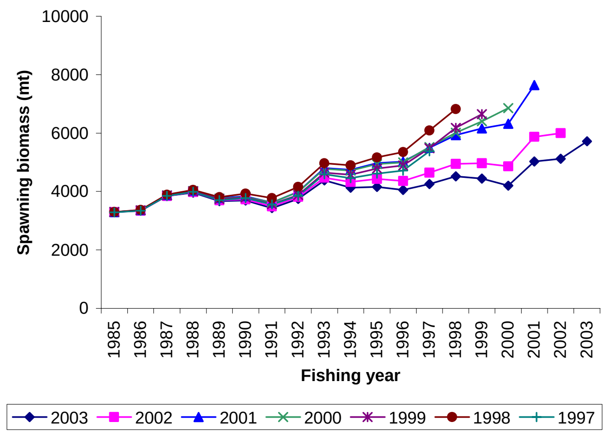
b. Recruitment



c. Total biomass



d. Spawning biomass



e. Selectivity

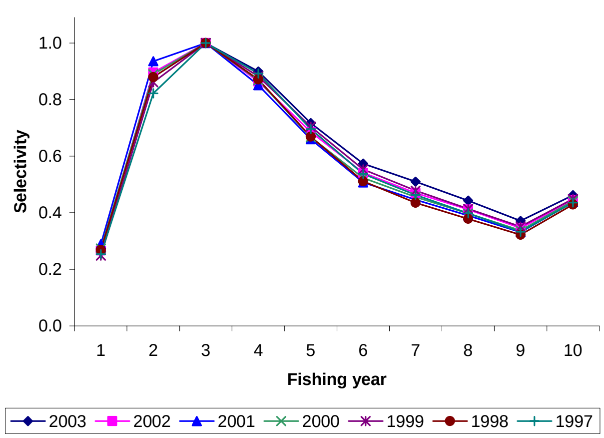
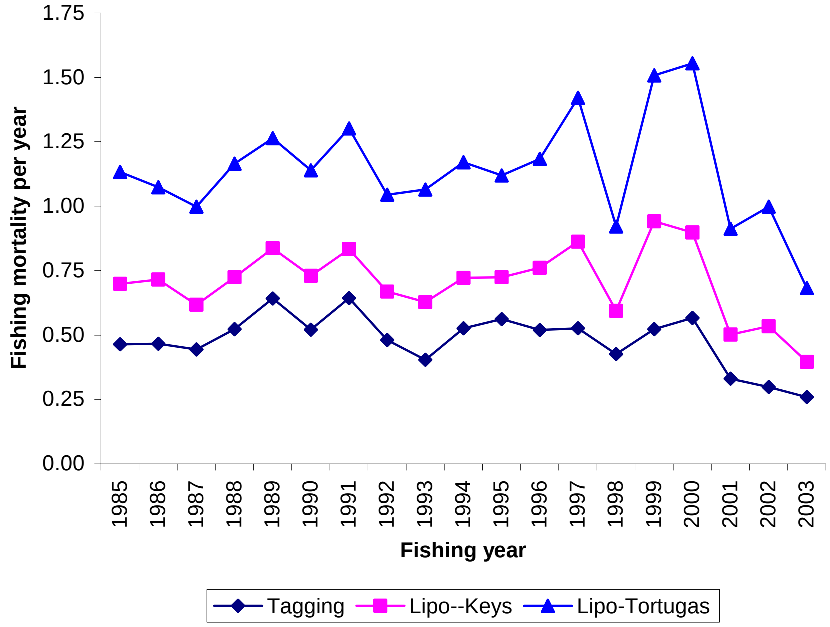


Figure 3.3.2.9(1). Retrospective analyses for the 1997-98 fishing year and later of different population parameters.

a.



b.

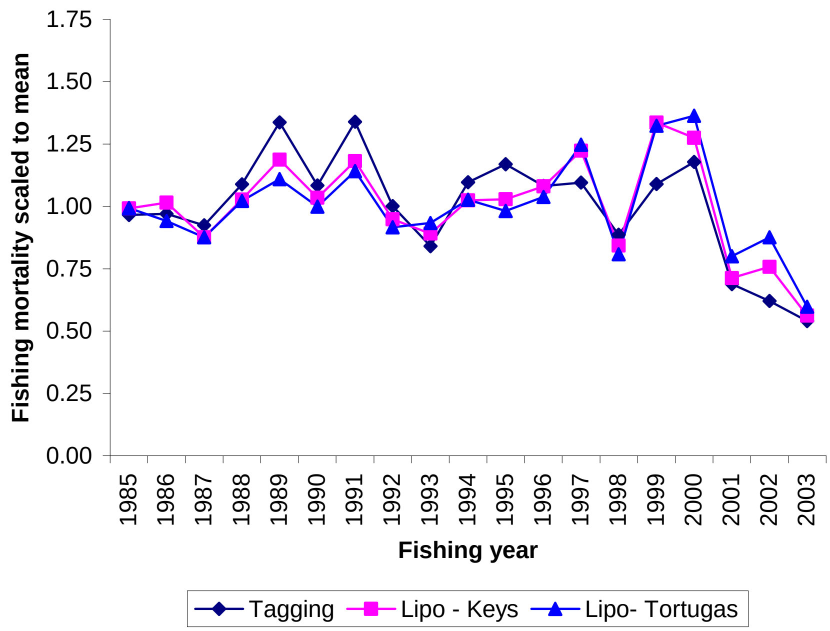


Figure 3.3.2.9(2). Comparison of fishing mortality rates on age-3 spiny lobsters estimated with three age-length keys: tagging, lipofuscin from Florida Keys and lipofuscin from the Dry Tortugas.

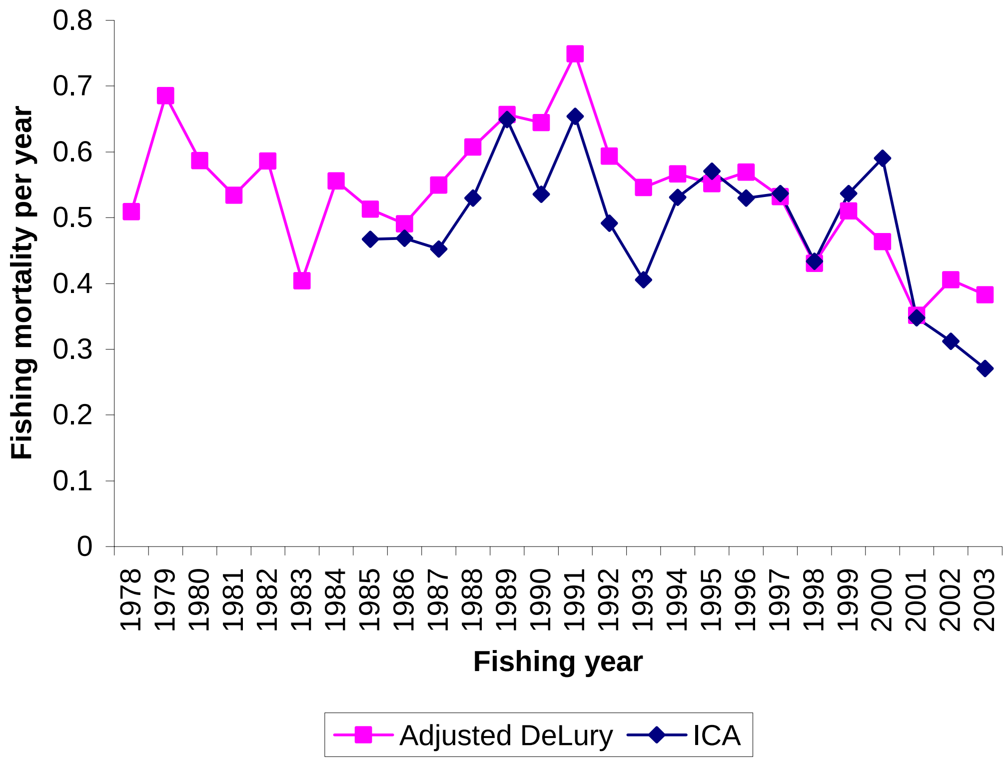


Figure 4.1. Comparison of the fishing mortality rates from the selectivity adjusted DeLury model and the age-structured model ICA.

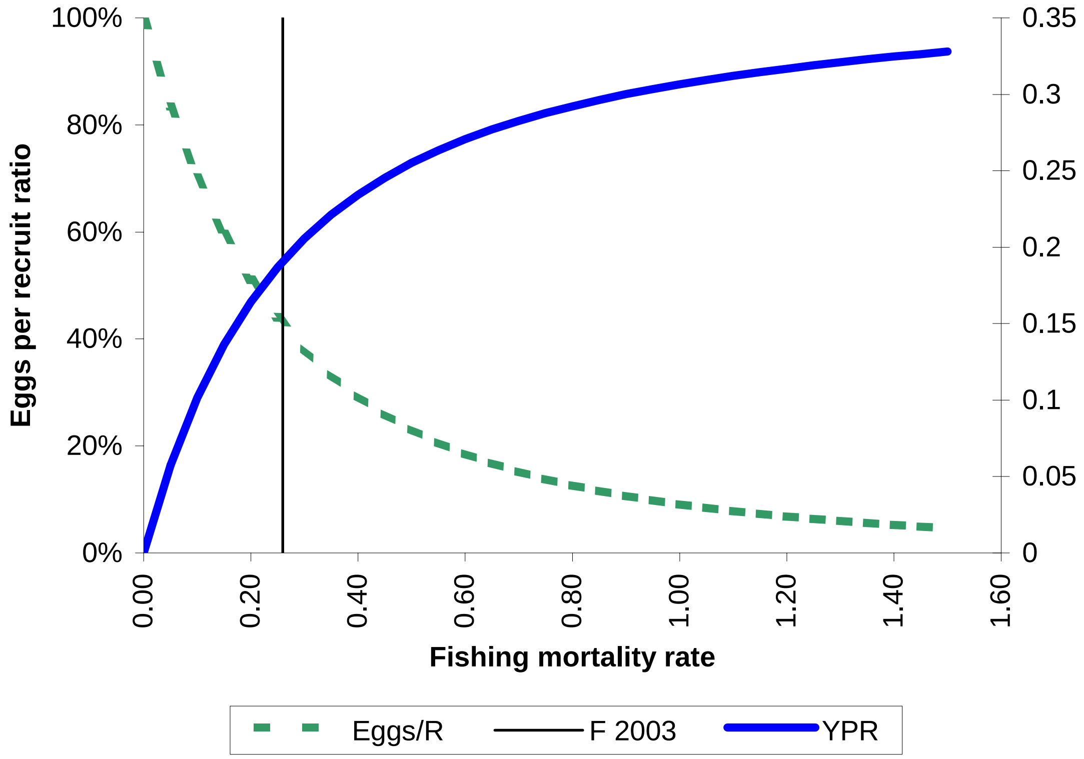


Figure 5.1.2. Yield-per-recruit and eggs per recruit ratio (Static SPR) by fishing mortality rates on fully recruited spiny lobsters. Also the fishing mortality rate in 2003-04 is also included.

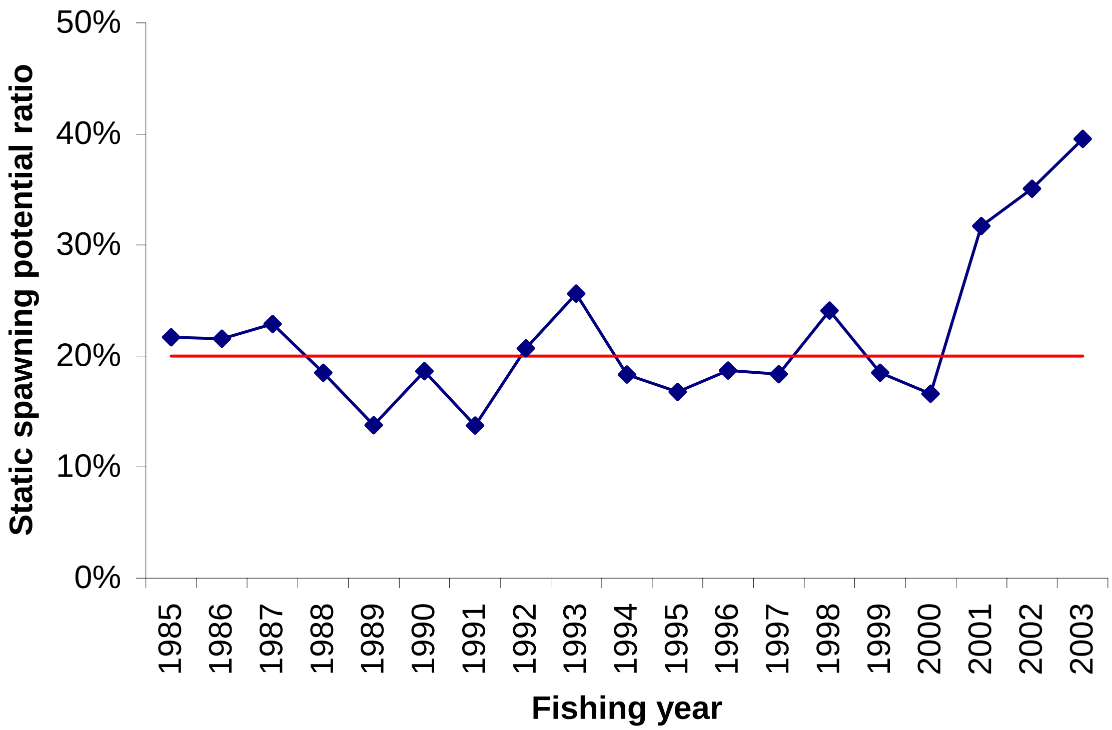
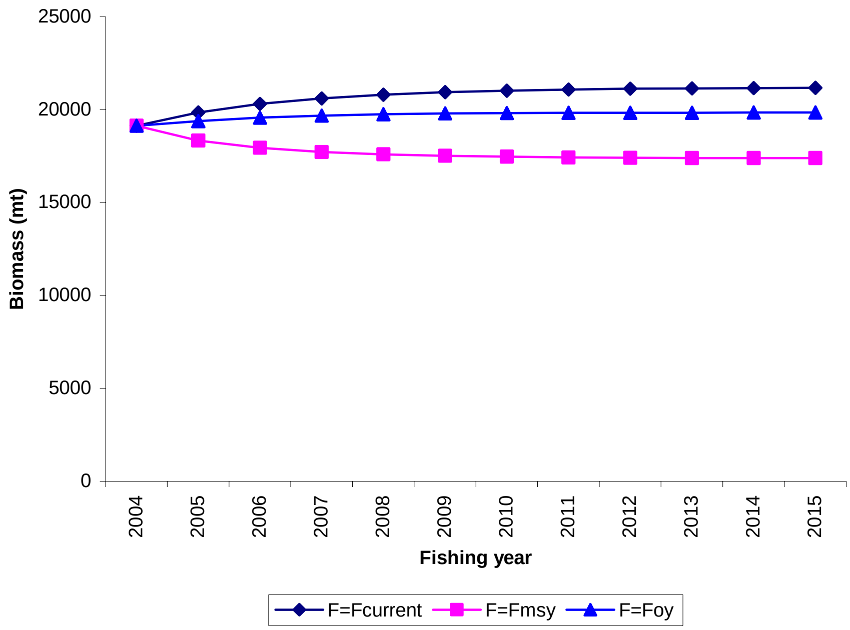


Figure 6.3. Static spawning potential ratios by fishing year and the current management objective of 20%.

a. Total biomass



b. Harvests

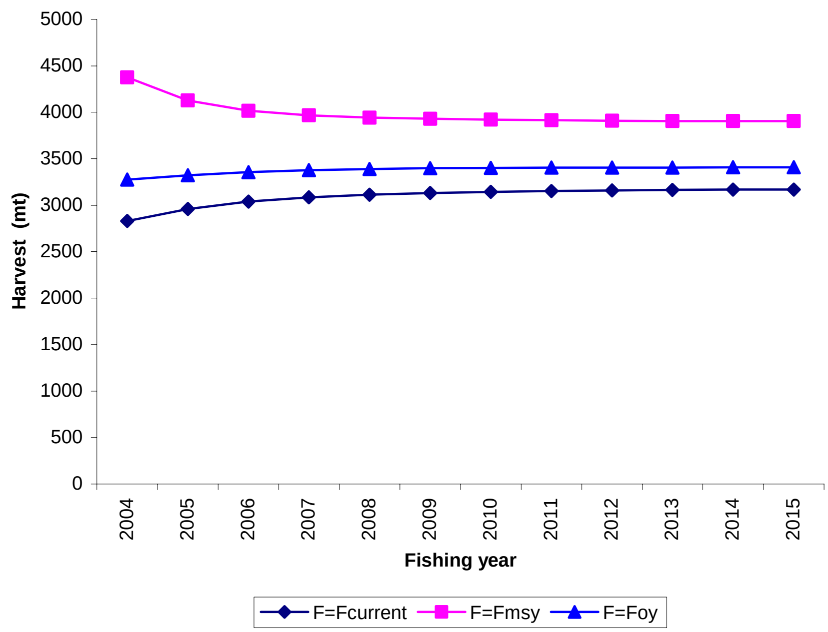


Figure 7. Projected biomass levels (a) and harvests (b) for three fishing mortality rates: Fcurrent, Fmsy, and Foy.

Appendix A – SEDAR Assessment Workshop Participants

Last Name	First	Affiliation	City	St	Telephone	E-Mail Address
Beaver	Rick	FWC	Marathon	FL	(305) 289-2330	rick.beaver@myfwc.com
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Gaitanis	Thomas	GMFMC	Dunnellon	FL	(352) 489-2887	linustag@aol.com
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SEDAR 8

Stock Assessment Report III

Southeastern US Spiny Lobster

SECTION IV. Review Workshop

SEDAR
1 Southpark Circle # 306
Charleston, SC 29414

Consensus Summary Report

Caribbean yellowtail snapper (*Ocyurus chrysurus*)
Caribbean spiny lobster (*Panulirus argus*)
South Atlantic – Gulf of Mexico spiny lobster (*Panulirus argus*)

Prepared by the SEDAR 8 Review Panel for:

Caribbean Fishery Management Council
Gulf of Mexico Fishery Management Council
South Atlantic Fishery Management Council

Edited by Andrew I. L. Payne for
SEDAR 8, 16-20 May 2005
San Juan, Puerto Rico

Executive summary

The SEDAR 8 Review Workshop met in San Juan, Puerto Rico, from 16 to 20 May 2005. The Panel itself comprised the Chair and a reviewer appointed by the CIE, four US technical experts, the SEDAR facilitator, and two stakeholder representatives. All documentation, including background documentation provided to earlier Data and Assessment Workshops, was provided to the Panel in good time for prior review, and was comprehensive for the job in hand.

The meeting considered three stocks, Caribbean yellowtail snapper, Caribbean spiny lobster, and South Atlantic – Gulf of Mexico spiny lobster. Able presenters had been assigned by the Assessment Workshops and went to great trouble to explain the background behind and the output from the assessments. For only one of these stocks, South Atlantic – Gulf of Mexico spiny lobster, were extensive additional runs requested during the meeting. Discussions for all three stocks focused on the assessments and what they meant in terms of the Review Workshop's Terms of Reference, the documentation of relevant comments about them, derivation of suggestions for future research and monitoring, and canvassing of stakeholder opinion. Finally, some time was spent evaluating the SEDAR assessment process in full, as requested.

For Caribbean yellowtail snapper, the data were deemed insufficient to provide a signal to underpin management advice, though the assessment methodology itself was sound. The importance of well-designed, systematic, long-term targeted research programs needed to construct adequate time-series of catch and abundance indices was stressed. Currently, it seems that data quality control independent of the data collection process has not been effectively realized, and validation of historical and future collections is urgently needed. Partnerships with fishermen are clearly one way to achieve this, and the need to look at the stock as part of a species assemblage or community was noted. Of the many research suggestions made, highest priority was assigned to the carrying out of fishery-independent surveys, the collection of more catch data, including specifically the recreational fishery, and the collection of age and length data from commercial and recreational catches and from fishery-independent surveys.

For Caribbean spiny lobster, the data were also deemed currently insufficient to provide the required management advice, though again the methodology applied was sound. The Panel noted that the data series could seemingly be split into two components, before and after about 1992, and focused much discussion on why this might be and how best to model it in future. Additional factors and modifications to the modelling approach were proposed for consideration in an attempt to understand better the dynamics of the population, and high priority was suggested be assigned to the creation of a standardized recruitment index. Other priority research and monitoring included incorporating historical data into existing data sets, and utilizing refined models (better to identify viable hypotheses). Partnerships with fishermen were again proposed to facilitate the data collection process.

In respect of South Atlantic – Gulf of Mexico spiny lobster, the data and assessments were accepted, as was the base-case ICA model of stock dynamics. Several further runs were requested and provided, but overall the base-case results were considered the best and not likely to be unreliable. Some time was spent discussing relative stock status with respect to overfished levels and the importance of this stock in terms of the whole population in the Western Atlantic. The various stocks likely primed each other with larvae and recruits. There was also strong support to re-establish an observer program for the commercial trap fishery. Other research priorities should include a broadening of the fishery-independent indices of abundance, the provision of improved growth information, perhaps through tagging, and

modelling of various scenarios covering a range of hypotheses concerning recruitment and changes in gear selectivity, as well as suitable performance indicators.

Comments on the SEDAR assessment process stressed: the need for better communication with and dissemination of information to stakeholders; the need for an advanced plan for assessments and a comprehensive glossary of terms; the continuity of personnel throughout each workshop process, in terms of stakeholders perhaps finding new ways of ensuring their participation; incorporation of fishermen's knowledge into the assessment process better; the need to maximize the time for preparing data series; the importance of independence in the review process, though not solely through CIE-contracted reviewers; and the importance of providing for the Review Panel an executive summary for substantive documents, a succinct table of model parameters, and if appropriate a table of management options.

1. Introduction

1.1 Time and Place

The SEDAR 8 Review Workshop met in San Juan, Puerto Rico, from 16 to 20 May 2005.

1.2 Terms of Reference for the Review Workshop

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.
2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.
3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation.
4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.
5. Recommend appropriate values for stock status criteria.
6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.
7. Recommend probable values for future population condition and status.
8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.
9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections;
10. Develop recommendations for future research for improving data collection and stock assessment.
11. Prepare a Consensus Report summarizing the peer review Panel's evaluation of the reviewed stock assessments and addressing these Terms of Reference. (Drafted during the Review Workshop with a final report due two weeks after the workshop ends.)

1.3 List of Participants

Participants	Affiliation
Review Panel:	
Andrew Payne	CIE, Chair
Paul Medley	CIE, Reviewer
Richard Appeldoorn	University of Puerto Rico
James Berkson	NOAA Fisheries/RTR Unit
Edward Schuster	St Croix Fisheries Advisory Cttee
Simon Stafford	GMFMC Advisory Panel
Ian Stewart	NOAA Fisheries/NWFSC
Doug Vaughan	NOAA Fisheries/SEFSC
Presenters:	
Liz Brooks	NOAA Fisheries/SEFSC
Nancie Cummings	NOAA Fisheries/SEFSC
David Die	University of Miami, RSMAS
John Hunt	Florida FWC
Robert Muller	Florida FWC
Mike Murphy	Florida FWC
Josh Sladek Nowlis	NOAA Fisheries/SEFSC
Francisco Pagan	University of Puerto Rico
Jerry Scott	NOAA Fisheries/SEFSC
Monica Valle	University of Miami, RSMAS
Observers:	
Mark Drew	Nature Conservancy, St Croix
Michon Fabio	CFMC Advisory Panel
Tony Iarocci	SAFMC
Joe Kimmel	NOAA Fisheries SERO
Barbara Kojis	US Virgin Islands DFW
Jimmy Magner	St Thomas Fishermen's Assn
Eugenio Pinero	CFMC
Julian Magras	St Thomas Fishermen's Assn
John Merriner	NOAA Fisheries SEFSC
Miguel Rolon	CFMC
Roger Uwate	US Virgin Islands DFW
Roy Williams	GMFMC
Staff support:	
John Carmichael	SEDAR
Cynthia Morant	SAFMC
Lloyd Darby	SEFSC
Graciela Garcia-Moliner	CFMC

1.4 Review Workshop working papers

An impressive quantity of documentation was provided before the meeting by the facilitator. Much of this pertained to material provided to either the Data Workshop or Assessment Workshop for each of the three review species. However, specific material for the review workshop itself was also provided, and this is listed below.

NUMBER	TITLE	Author
	Working Papers	
SEDAR8-RW1	Further explorations of a stock production model incorporating covariates (ASPIC) for yellowtail snapper (*Ocyurus chrysurus*) in the US Caribbean	J. Sladek Nowlis
SEDAR8-RW2	Length frequency analysis of Caribbean spiny lobster (*Panulirus argus*) sampled by the Puerto Rico commercial Trip Interview Program (1980-2003)	S.D. Chormanski, D. Die, S. Saul
SEDAR8-RW3	Maturity of spiny lobsters in the US Caribbean	D. Die
	Supplementary Documents	
SEDAR8-RD24	Preliminary estimations of growth, mortality and yield per recruit for the spiny lobster *Panulirus argus* in St. Croix, USVI. *Proc. Gulf Carib. Fish. Inst.* 53: 59-75	I. Mateo, W.J. Tobias
SEDAR8-RD25	Population dynamics for spiny lobster *Panulirus argus* in Puerto Rico: Progress report. *Proc. Gulf Carib. Fish. Inst.* 55: 506-520	I. Mateo
	Assessment Reports	
SEDAR8-SAR1	Stock assessment report for Caribbean yellowtail snapper	J. Sladek Nowlis
SEDAR8-SAR2	Stock assessment report for Caribbean spiny lobster	J. Sladek Nowlis
SEDAR8-SAR3	Stock assessment report for South Atlantic – Gulf of Mexico spiny lobster	R. Muller, J. Hunt

2. Terms of Reference

2.1 Background

Generally, the Review Workshop is the third meeting in the SEDAR process, and this situation pertained to all three stocks reviewed during SEDAR 8. The Panel was pleased to be able to record that the terms of reference set for Data Workshops and Assessment Workshops for the three stocks were fully met, but there was some concern expressed that pressure may have been brought to bear on participants at some of those workshops to progress management further than was possible from the available data. Quite simply, data time-series, and in some cases recent basic biological data, were likely unable to support the development of meaningful assessments for the stocks just yet.

Notwithstanding, the Panel was impressed by the quantity and quality of the work that had gone into the various assessments. The presentations were well structured and clear, and the information provided through the presentations, and in response to questions, gave an excellent basis for the Panel's subsequent deliberations and conclusions.

2.2 Review of the Panel's deliberations

The deliberations on each species are presented in the form of responses to the terms of reference questions specifically, followed by relevant comments on the discussions, suggestions for future research, and stakeholder opinion, the last two not specifically in order of priority.

A. *Caribbean yellowtail snapper*

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.
The data were treated appropriately, but were not adequate yet for assessing the stocks.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.
The two methods were appropriate for exploring the potential for an assessment, but ultimately merely showed the inadequacy of the data. Nonetheless, the methods are scientifically sound, if given appropriate data.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation.
An acceptable assessment had not been developed, so appropriate population parameters were not produced.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.
An acceptable assessment had not been developed, so estimates of stock status criteria were not produced.

5. Recommend appropriate values for stock status criteria.
An acceptable assessment had not been developed, so appropriate stock status criteria were not produced. Although a number of key reference points were provided (B_{msy}/B_0, SPR_{msy}, F_{msy} – given selectivity vector) and seem to be robust across the various models, they do not provide information on current stock status.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.
No population projections were possible.

7. Recommend probable values for future population condition and status.
No population projections were made or possible, so probable values for future population condition and status were not produced.

8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.
All desired and necessary assessment results are clearly and accurately presented in the Stock Assessment Report for the species, but they are currently uninformative on stock status. These results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.
The Data Workshop fulfilled its Terms of Reference. The Assessment Workshop fulfilled its Terms of Reference to the extent possible, given the limitations of the data.

10. Develop recommendations for future research for improving data collection and stock assessment.
See below the comments section.

<u>Comments</u>

The Review Panel offers the following comments regarding research needs and the data and assessment of yellowtail snapper.

1. Well-designed, systematic research programs are essential to providing the data necessary for effective management. Much of the research reviewed lacked the necessary sample sizes and regular (ongoing) data collection needed to construct an adequate time-series of catch and abundance indices.

2. The yellowtail snapper fishery is unique among Caribbean fisheries with regard to fishing methods and timing, and the needed research designs. It is an important fishery in the U.S. Caribbean. The design of data collection must take into account the unique aspects of the fishery, and therefore sampling effort will need to be either added or redirected to target yellowtail snapper more effectively.

3. A commitment to long-term research and data collection is essential for effective management. Short-term research and data collection are not the solution to the data

problems identified in this assessment. Long-term research and monitoring are necessary in the Caribbean, as in any other managed fishery. Based on the studies and data available, it is clear that the resources necessary to collect essential data are not currently available to support scientifically based management of yellowtail snapper in the region.

4. Throughout the region, data quality control independent of the data collection process has not been effectively realized. Validation of historical and future collections is needed for the data to be used appropriately for any type of assessment. Documentation of changes in data collection and management methods must be maintained and provided to those charged with conducting the assessments and reviews.

5. The Panel recognizes the significant effort that has been put into data collection in the region and emphasizes that, although the resulting data are insufficient for an assessment at this time, they will be useful for assessment in future when combined with additional data identified elsewhere in this report. Past efforts are not wasted, but rather their data will play an important role, providing the temporal contrast needed by assessment models. The recommendations below are offered as improvements to the current data collection, not as replacements.

6. The Panel strongly endorses the need to develop partnerships with local fishermen to conduct research and to collect needed data. Partnerships with the fishing community and other stakeholders are a cost-effective way to collect components of the data necessary for the assessment process. Currently, it is clear that there is a high level of interest in the fishing community to cooperate with management agencies in collecting data, and this partnership should be encouraged and strengthened. This would also facilitate ongoing cooperation and participation by fishermen in the management process, benefiting all involved.

7. Monitoring and assessment of yellowtail snapper should be undertaken with due consideration given to the species' importance in the overall species assemblage and community. Future ecosystem management will likely dictate such a course of action.

Recommendations for future data collection and research

Fishery-independent data

- A new independent sampling regime to target yellowtail snapper more effectively should be created, because current methods do not allow temporal or spatial coverage.
- Visual surveys can provide useful fishery-independent data. The methods would, however, vary, based on the depth of the insular shelf.
- The output of other existing studies (NOAA and non-NOAA) should be examined to see if alternative fishery-independent sampling already exists.

Life history data

- Fecundity data should be collected
- Maturity data should be collected
- Growth information should be collected
- The parameter natural mortality needs investigation on the basis of better data

Catch data

- Recreational catches need to be sampled and quantified better
- Information on trip species targeting is needed
- Information on the location of catches is sometimes not good, and should be improved
- Identification of species in the snapper complex in the US Virgin Islands is crucial to future assessments
- Historical data from the US Virgin Islands need to be collected from fishermen, if they exist
- Port samplers need to modify their schedules to target yellowtail snapper landings, and to sample sizes of the species need to increase
- TIP sampling in the US Virgin Islands needs to be revitalized

Age and length frequency data

- These are needed from all commercial catches
- These are urgently required from recreational catches
- Fishery-independent surveys can provide these crucial data

Genetic / otolith microchemistry studies

- Stock structure is important in assessments, and genetics and otolith microchemistry offer hope to unravel it in future

Spatially explicit studies

- Identification of spawning areas and the source of recruits is important
- Construction of habitat maps will help identify stratification for research designs
- Combination of habitat maps with fish counts and habitat models will aid in providing population estimates
- Development of a GIS map of yellowtail snapper landings throughout the species' geographical range could help in the production of a distribution map of catches

Mark-recapture studies

- This could help identify movements and migrations
- Fishing mortality estimates could be derived
- Population estimates would be enhanced with such studies
- Such studies could help solve the perplexing question of stock structure

Of the above, the Panel places the highest priority on the following, understanding the need to maximize the likelihood of generating an acceptable assessment of the stock in the near future:

- The carrying out of fishery-independent surveys
- Collection of more catch data, including specifically the recreational fishery
- The collection of age and length data from commercial and recreational catches and from fishery-independent surveys

<u>Stakeholder opinion</u>

- The need for robust education of fishermen and other stakeholders is acknowledged. Such education should be of a two-way nature and would potentially lead to an enhancement of their trust in the assessment and management process, especially if they were to become involved in research program design.
- The fact that most of the product in the yellowtail snapper fishery is sold retail and that there are no fish houses (at least in the US Virgin Islands) makes any meaningful future stock assessment in the region extremely dependent on cooperation with the local fishermen.
- A paucity of recent socio-economic information continues to hinder the development of integrated biological, economic, and social assessments.
- Partnerships with organizations such as NGOs, which are often staffed by highly qualified people and are perhaps also less constrained by political influence, can mobilize extra resources in meeting some of the research objectives.
- Biological and habitat/ecosystem research information is as important in the assessment process as catch data.
- Over the past 35+ years of fishing, yellowtail snapper abundance has remained stable.
- Detailed data (information) on yellowtail snapper catch are lacking for US Virgin Islands commercial landings. The lack of this type of data has introduced uncertainty into the determination of stock status. Therefore, collection of detailed catch information there is suggested as a top research priority.

B. *Caribbean spiny lobster*

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.
The data were treated appropriately, but they were not sufficiently informative to assess stock status. An alternative explanation is that the data may be inconsistent with the assumptions of the models being applied.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.
The methods were appropriate to explore the potential for an assessment, but ultimately were limited by the uninformative nature of the data. The Panel expressed some concern about the method used to standardize the stock abundance indices. The GLM and delta-lognormal approach is appropriate, but determining terms in the model based purely on statistical criteria can lead to bias in the index. Future assessment workshops need to reconsider how the various effects might influence an abundance index, and choose to test GLM terms accordingly.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation.
It had not been possible to produce an acceptable assessment so appropriate population parameters were not recommended.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.
An acceptable assessment had not been developed, so estimates of stock status criteria were not produced.

5. Recommend appropriate values for stock status criteria.
An acceptable assessment had not been developed, so appropriate stock status criteria were not produced. Analysis of % catch under minimum size coupled with other YPR studies showed the current minimum size to be appropriate to maximize YPR, and trends in relative abundance indices and length distributions indicate some stability over the past 20 years, but these results do not provide information on stock status. YPR analyses suggest that the Caribbean spiny lobster fishery is not experiencing growth-overfishing (i.e. the ratios of current to MSY-level exploitation rates were consistently <1). Although it would be tempting to draw a specific conclusion on stock status from this information, there are a number of reasons to avoid doing so. The recruitment-based models indicated a wider range of uncertainty regarding overfishing, and the YPR analyses were limited by assumptions about key parameters (e.g. natural mortality, stock-recruitment shape) and a limited time frame. Consequently, the Review Panel concluded that Caribbean spiny lobster stock status remained unknown.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.
No population projections were possible.

7. Recommend probable values for future population condition and status.
No population projections were possible, so probable values for future population condition and status were not produced.

8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.
All desired and necessary assessment results are clearly and accurately presented in the Stock Assessment Report, but they remain uninformative on stock status. The results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.
The Data Workshop fulfilled its Terms of Reference. The Assessment Workshop fulfilled its Terms of Reference to the extent possible, given the limitations of the data.

10. Develop recommendations for future research for improving data collection and stock assessment.
See below the comments section.

<u>Comments</u>

1. With the available data, an interesting story becomes evident. The data series can seemingly be split into two components, before and after about 1992. In the first part of the time-series, the abundance indices decline. The models were able to recreate the decline in nominal CPUE on Puerto Rico / St Thomas / St John. This is a common pattern found in exploited fish populations, biomass steadily decreasing, and fishing mortality steadily increasing. The second part of the time-series shows the abundance index remaining steady while the catch increases, a trend inconsistent with our expectation of a fishery in a closed system. As catch increases above the level that was causing a population decline in the first portion of the time-series, we would expect the abundance index either to continue to decline or for the decline potentially to accelerate. Instead, the abundance index levels off as the catch increases. Because of this situation, standard production model approaches do not fit the entire time-series, because they do not have the ability to recreate the observed behavior.

The Panel therefore suggests that additional factors be considered in an attempt to understand better the dynamics of the population. One possibility is that recruitment may have increased during the second half of the time-series, allowing for increased catch without reducing population size. Another possibility is that fishermen may have moved into new areas, accessing a previously unexploited portion of the population, so allowing for increased catches. Other possible hypotheses involve changes in the gear used, or in post-settlement survival, and/or changes in post-larval settlement rates.

It should be possible to modify the modelling approach to produce a model that would support the observed data. One way to do this would be to allow the recruitment parameter r to increase over the second part of the time-series. This would require refining a model unique to the system, perhaps moving beyond the standard modelling software currently used. Once a model can recreate the behavior observed in the data, it should be possible better to identify hypotheses for the cause of the behavior.

Clearly, understanding the dynamics of recruitment in this fishery is crucial. There is therefore a great need to create a standardized annual recruitment index to support any assessment of this stock.

2. The Panel strongly endorses the development of partnerships with local fishermen, to conduct research and to collect the data needed for assessments. Partnership with the fishing community is a cost-effective way to collect components of the needed data. Currently, there is a high level of interest in the fishing community to cooperate with management agencies in collecting data, so the partnership should be encouraged and strengthened. This would also facilitate ongoing cooperation and participation by fishermen in the management process, benefiting all involved.

Recommendations for future data collection and research

Improve and complete historical data on relative abundance indices and catch

- For the commercial fishery
  - Recover pre-1983 data for Puerto Rico
  - Create/recover pre-1975 data for the US Virgin Islands by working with the fishermen's associations
  - Use the newly available US Virgin Islands data for the period 1987–1992
  - Use structured interviews with fishermen to assess gear changes
- For the recreational fishery
  - Estimate historical and current levels

Fishery–independent monitoring

- The Panel identified an apparent inconsistency between the assessment model assumptions of recruitment as a direct function of spawning stock. This appeared to be important enough to warrant two recommendations: 1) to build additional flexibility into the models to allow time-varying recruitment (or at least recruitment dynamics); and 2) to seek to establish a fishery-independent index of recruitment, which is deemed to be crucial. Based on presentations made during the review, there appears to be a tested method for conducting such a survey, and these types of data are currently being used in the SA-GOM lobster assessment. The method consists of placing a series of post-larval collectors in appropriate areas and consistent sampling their catch. This approach appears to be conducive to cooperative research, utilizing fishermen's knowledge of the area as well as their frequent visits to sampling areas. The Panel strongly endorses the need for such a survey to provide a data series for use in the Caribbean spiny lobster assessment, preferably with a sampling design covering both platforms, given the uncertainty about the spatial coupling of recruitment dynamics
- It is necessary to develop and implement sampling program(s) specific to both pre-recruit and adult Caribbean spiny lobsters
- It is crucial to increase sampling effort in the US Caribbean.
- There will be benefit in further diversifying the regions sampled to include equal coverage of areas frequently fished
- Visual surveys for size structure, abundance, and YPR could provide useful time-series of data

Revise the trip interview program (TIP) database exhaustively

- Completing the historical data set would be valuable
- Revitalizing TIP sampling in the US Virgin Islands would have many benefits, not just for the Caribbean spiny lobster stock
- Effort should be directed at key species, generating trip-target information, and obtaining needed detail

Length distribution of the catch

- For the commercial fishery
  - Complete incorporation of non-digitized data for the US Virgin Islands (TIP)
  - Recover historical length data for Puerto Rico and the US Virgin Islands from other studies prior to the TIP

- For the recreational fishery
  - Determine length distributions

Conduct studies to understand the ecology of early juveniles (25 mm carapace length)

- Habitat use needs to be understood better
- More needs to be known about settlement habitat
- Information on movements and migrations needs to be sought
- Clarity of the mortality rates needs to be sought

Spatially explicit studies

- Identify spawning areas and sources of recruits
- Build/acquire habitat maps to identify stratification for research designs
- Combine habitat maps with density counts and habitat models to provide population estimates
- Develop a GIS map of spiny lobster landings throughout the geographic range of the stock, producing catch distributions

Mark-recapture techniques

- Such studies could hone knowledge of abundance
- The techniques could provide additional information on movements and migrations
- Habitat preferences would be better understood

Stock structure

- Stock structure is important in assessments, and genetics offers hope to improve knowledge

Future assessments

- These should explore further use of length structure and density from closed areas as reference points
- Assessments need to be repeated when significant quantities of previously unavailable historical data have become available
- Alternative stock assumptions need to be considered during assessment
  - That of a wider Caribbean stock
  - That of the stock of the US Caribbean and neighboring islands
- The use of nominal CPUE should be considered in future assessments
- The modelling approach needs to be modified to produce a model that would support the observed data. Within the model, the recruitment parameter r should be allowed to increase over the second part of the time-series, perhaps moving beyond the standard modelling software currently used.

Of the above, the Panel places the highest priority on the following, understanding the need to maximize the likelihood of generating an acceptable assessment of the stock in the near future:

- Develop/strengthen fishery-independent data collection
- Incorporate historical data into existing data sets
- Utilize refined models (better to identify viable hypotheses)

Stakeholder opinion

- Priority should be given to research that supports efforts to collect new catch data and increase port sampling. Research efforts should foster involvement of and collaboration with fishers.
- The fact that most of the product in the Caribbean spiny lobster fishery is sold retail and that there are no fish houses (at least in the US Virgin Islands) makes any meaningful future stock assessment extremely dependent on cooperation with the local fishermen.
- There is need at least to explore approaches to identify and incorporate socio-economic and other data types into the model. Some such data may indirectly be reflected but still influence CPUE, and may be available for 20 years or more. Examples are (i) employment; (ii) fuel costs; (iii) coastal development, e.g. on St Croix the number of homes per hectare is a significant predictor of water quality, and water quality may impact habitat and species populations; (iv) km of roads; (v) average *per capita* income.

C. *Spiny lobster in the Southeast United States*

Introduction

A comprehensive overview of the data and models used for the SE lobster assessment was provided. The assessment models explored included ASPIC, a modified DeLury model, catch-curves, untuned VPA, and an integrated catch-at-age (ICA, developed by Ken Paterson) model. The results presented focused primarily on the DeLury and ICA models, with ICA the preferred base-case assessment model.

Panel requests for further analyses during the meeting

1. Additional sensitivity runs using the ICA model, intended to explore the effect of the base-case selectivity assumptions on the results:

- Try an alternate year (>1993) to transition from estimated to constant selectivity
- Try constant selectivity in the early period, then estimated selectivity thereafter, if possible.

The values estimated with three alternative selectivity assumptions were very close to the base-case model result. However, the CVs of recent fishing mortality did increase when the shortest period of constant recruitment was assumed. The second part of the request was not feasible using the current model framework. The Panel was nevertheless satisfied that the base-case results were not likely to be unreliable as a consequence of the selectivity assumptions used.

2. Try a run estimating natural mortality (M) using the DeLury model.

On attempting this, M was not considered to be reliably estimated, but the value used in the base-case model did appear to be consistent with the data.

3. Explore alternative methods for projecting future recruitments with uncertainty, possibly including

- Extrapolation of the recent estimated trend
- Re-sampling from residuals about the mean
- Re-sampling from Monte-Carlo results

A projection including variability in model parameters was completed. The qualitative results were similar for projections based on $F_{current}$ *and* $F_{20\%}$*, although projected harvest levels were somewhat lower than the deterministic values. The Panel was satisfied that the approach adequately reflected uncertainty in future projections.*

4. Subsequent to the first three requests, an additional request was made to produce a decision or scenario table based on the model runs already completed and evaluated by the Panel.

Three alternate recruitment scenarios were presented: similar to the last 12 years, similar to the last 4 years, and based on a stock-recruit curve. Respectively, these roughly corresponded to two levels of constant (high and low) recruitment, and to stock-sensitive recruitment. Three alternate management targets were simulated through F values of $F_{5\%}$*,* $F_{20\%}$ *and* $F_{30\%}$*. However, after reviewing a series of results from this analysis, the Panel concluded that no further material needed to be included in this report or for them to formulate their decisions.*

Terms of reference

1. Evaluate whether data used in the analyses are treated appropriately and are adequate for assessing the stocks; state whether or not the input data are scientifically sound.
The data used in this assessment were treated appropriately and are considered fully adequate to assess the stock.

2. Evaluate the adequacy, appropriateness, and application of the methods used to assess the populations; state whether or not the methods are scientifically sound.
The methods used in this assessment were adequate, appropriate, and scientifically sound.

3. Recommend appropriate or best-estimated values of population parameters such as abundance, biomass, and exploitation.
The base-case assessment model provided the best estimates for these values.

4. Evaluate the adequacy, appropriateness, and application of the methods used to estimate stock status criteria (population benchmarks such as MSY, F_{msy}, B_{msy}, MSST, MFMT). State whether or not the methods are scientifically sound.
Because of the lack of direct linkage between spawning stock and subsequent recruitment, there is no comparable proxy benchmark for SSB. For this reason, SSB/SSB_{msy}, MSY, and related criteria could not be estimated. A proxy benchmark for F was available from the SAFMC Fishery Management Plan for Spiny Lobster (Amendment 6) based on static SPR (F_{oy} = 30% SPR, and $F_{msy\ proxy}$ = 20% SPR). The method used in this assessment for estimating stock status criteria for F was adequate, appropriate, and scientifically sound.

5. Recommend appropriate values for stock status criteria.

There was considerable discussion as to whether the $F_{20\%}$ threshold makes biological sense, given that values are likely to be close to this level under historical rates of fishing mortality. It was noted that, if all portions of this Caribbean stock had high fishing mortality rates, this might not be biologically reasonable over longer time-scales. The long-term average is currently estimated to be SPR = 19%, presumed to be sustainable though slightly below the limit. The Panel concluded that there was no basis for recommending alternative benchmarks. Based on the assessment model results presented, overfishing does not appear to be occurring at the moment. Indeed, there is no evidence that growth-overfishing would occur even at very high rates of fishing mortality, given current estimated selectivity patterns. However, the stock status relative to overfished levels cannot be evaluated.

6. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status and, if appropriate, evaluate stock rebuilding; state whether or not the methods are scientifically sound.

The methods used in this assessment were adequate, appropriate, and scientifically sound. The Panel preferred the revised projections including uncertainty in estimated model parameters.

7. Recommend probable values for future population condition and status.

There was no indication that future population conditions and status would be below the current levels reported from the base-case assessment model.

8. Ensure that all desired and necessary assessment results (*as listed in the SEDAR Stock Assessment Report Outline*) are clearly and accurately presented in the Stock Assessment Report and that such results are consistent with the Review Panel's consensus regarding adequacy, appropriateness, and application of the data and methods.

The necessary results fulfilling the SEDAR stock assessment report outline were presented. Additional analyses were performed in response to requests made by the Panel, the summary results of which are included in this report.

9. Evaluate the Data and Assessment Workshops with regard to fulfilling their respective Terms of Reference and state whether or not the Terms of Reference for previous workshops are adequately addressed in the Data Workshop and Stock Assessment Report sections.

The Data and Assessment Workshops appeared to have met their respective terms of reference fully.

10. Develop recommendations for future research for improving data collection and stock assessment.

See below the comments section.

Comments

The Review Panel offers the following comments regarding research needs:

1. Discussion of the ability to estimate the relative stock status with respect to overfished levels focused on the connectivity of the entire Caribbean spiny lobster population and the relative importance of the SA-GOM area in the total. It was noted that catches from the area make up <10% of the catch in the western Atlantic, and that present understanding of oceanographic patterns indicates that it is quite likely that the area receives larvae from other areas. This statement is based on the duration of the larval period and the speed and direction of prevailing currents. Critical information required to evaluate fully whether the stock is overfished include: identifying the source of the larvae settling in the SA-GOM area as well as determining the proportion of larval production from the area that is retained locally. A broad assessment of the Caribbean population would be desirable, but is impractical at this time.
2. There was support from both stakeholders and scientists at the Panel to re-establish an observer program for the commercial trap fishery. This program could supply useful data to be used directly in the present assessment model including: an index of pre-recruit numbers, adults, and other information that cannot be gained through other methods. Efficient coordination and communication between participants (both industry and scientists) must be a priority in planning this program. The Panel recognized that the program will be most valuable as the duration of the time-series increases, and planning should reflect this.

Recommendations for future data collection and research

Data from the commercial fishery
- Re-establish a commercial fishery observer program (described above).

Fishery-independent indices of abundance
- Standardize existing data sets that may be used for juvenile and legal-sized indices of abundance
- Design new monitoring programs to collect systematic, consistent, and statistically rigorous data.

Improved growth information
- Tagging projects should be initiated to obtain growth-rate data from larger (CL >100 mm) lobsters
- Activity may need to be focused in areas of reduced exploitation (such as the Tortugas) to allow capture of these larger individuals in appreciable numbers
- Reconcile growth information from Lipofuscin and tagging data

Modelling
- Conduct Monte Carlo simulations to test $F_{20\%}$ and $F_{30\%}$ threshold and target reference points against various performance criteria. The stock assessment workshop for the stock should develop various scenarios covering a range of hypotheses concerning recruitment and changes in gear selectivity, as well as suitable performance indicators, including catch and measures of SSB. Risks in the performance indicators associated with applying the threshold and target should be generated in future assessments.

Stakeholder opinion

- Fishing pressure has decreased in the Keys because (i) there are less traps as a result of the Trap Certificate Program, (ii) recent efforts to curtail a rapidly expanding illegal dive fishery, (iii) the loss of dock space and subsequent selling out as gentrification continues at an increasing rate, (iv) the loss of suitable crew as a direct consequence of the increasing cost of living in the Keys.
- Fishermen are very willing to sit down with scientists to devise long-term observer/sampling programs that enmesh with operational activity and satisfy crucial needs for data.

2.3 Recommendations for future SEDAR assessments

In terms of the terms of reference provided to the Review Workshop, opportunity was given to all participants (as well as to the Review Panel) to comment upon the whole SEDAR assessment process. What follows is a non-prioritized list of the main points made.

- There is a strong need for enhanced communication, specifically to stakeholders, about what SEDAR is trying to achieve in terms of management.
- To date, there has not been full acceptance from all, and this is put down at least partially to the lack of education and training of certain key parties about the process. Their cooperation is essential if SEDAR is to succeed in its objectives.
- An advanced plan of what species is to be handled when is essential for all those who need and wish to be involved in the process.
- There is need for a (web-based) Glossary of Terms used.
- Continuity of personnel in the workshops is crucial to ensuring both acceptance and enhanced understanding.
- Dissemination of the information created and the results in terms of management action are not always perceived by stakeholders to have been achieved, so it was felt that Councils should make greater effort in this regard, at all levels of the process.
- Several participants, both technical and representing fishermen, felt that greater effort should be made to maximize the time for preparation of data series, assessments, and review material. The Panel shied away from suggesting a deadline for receipt of material prior to each workshop, realizing that the very nature of some data would always make collection to the last possible moment necessary, but stressed that late receipt could easily lead to delayed or less informative assessments of stock status.
- As mentioned several times elsewhere in this report, strong cases were made for incorporating fishermen's knowledge better into the assessment and management process.
- The Review Panel requires the presence of scientists who have not been involved in the Data and/or Assessment Workshops. This may not be a preferred requirement for the participating stakeholders. Stakeholders would clearly benefit and be better able to participate fully in the review process if they had been present throughout all meetings. The Councils could maximize meeting this recommendation by considering paying stipends to participating stakeholders to compensate them for lost earnings.

- There was strong feeling that the anticipated changed representation on the Review Panel may not be most appropriate for the SEDAR area. While understanding and wholeheartedly endorsing the need for independent peer review, a strong case could be made for Panel representation to include stakeholders, biologists knowledgeable about the species, and stock assessment scientists who were not involved in the immediate assessment. It was felt unlikely that such people would be able to participate in the discussions at the current enthusiastic level unless they were formally accepted as members of the Panel.
- Allied to the above and notwithstanding what was ultimately decided on the make-up of the Panel, there was unanimity that the independence of the Review Panel chair (currently appointed by the CIE) was paramount and matched well the objective of independence.
- Given the volume of documentation associated with such reviews and the shortage of time often available to assimilate it, the Review Panel and other participants stressed the need for a clear executive summary to be provided for all substantive documents being addressed. Further, there was a call for a succinct table of model parameters (estimated and observed) to be provided for each assessment along with, if appropriate, a table of management options (e.g. a decision table) and the risks associated with them.