

SEDAR

Southeast Data, Assessment, and Review

SEDAR 91

Stock Assessment Report

US Caribbean Spiny Lobster – Puerto Rico

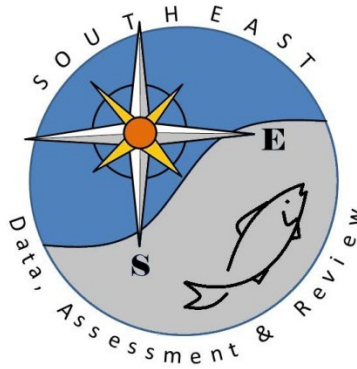
September 2025

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SEDAR



Southeast Data, Assessment, and Review

SEDAR 91

US Caribbean Spiny Lobster – Puerto Rico

SECTION I: Introduction

SEDAR
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Overview

SEDAR 91 addressed the stock assessment for US Caribbean Spiny Lobster – Puerto Rico. The process consisted of an in-person Data Workshop, with several webinars before and after the workshop and a series of assessment webinars. The Review Workshop was cancelled because the center for independent experts (CIE) were not able to participate in the review of the assessment. The assessment was conducted by the SEFSC.

The Stock Assessment Report is organized into 4 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. The Data Workshop Report can be found in Section II. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Process report. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the data workshop. Consolidated Research Recommendations from all stages of the process can be found in Section IV for easy reference.

The final Stock Assessment Report (SAR) for US Caribbean Spiny Lobster – Puerto Rico was disseminated to the public in September 2025. The Council’s Scientific and Statistical Committee (SSC) will review the SAR. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The Caribbean Council’s SSC will review the assessment at its September 2025 meeting, followed by the Council receiving that information at its December 2025 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

1 SEDAR PROCESS DESCRIPTION

SouthEast Data, Assessment, and Review (**SEDAR**) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. SEDAR seeks improvements in the scientific quality of stock assessments and the relevance of information available to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

SEDAR is managed by the Caribbean, Gulf, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; a representative from the Highly Migratory Species Division of NOAA Fisheries, and Interstate Commission

representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is normally organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a workshop and/or a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final step is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 stages and all supporting documentation, is then forwarded to the Council SSC for certification as ‘appropriate for management’ and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Cooperator. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

2 MANAGEMENT OVERVIEW

A Management History Database is being compiled, cataloged, and standardized by the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), the Southeast Fisheries Science Center (SEFSC) Fisheries Statistics and Sustainable Fisheries Divisions in collaboration with the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) of the University of Miami.

The Management History Database effort involves:

- Identifying Federal Register documentation associated with management actions affecting federally managed species throughout the Gulf of Mexico, South Atlantic, and U.S. Caribbean regions.
- Creating standardized records specifying the Fishery Management Plan (FMP), species, jurisdiction, and fishing sector (commercial and recreational) to which each management action is applied.

Once complete, the goal of the database is to provide a comprehensive and standardized record of published management actions to increase the efficiency of fisheries stock assessments, ACL monitoring, and ecosystem approaches. However, the database is still in development and is not yet available to the public. The intention of this working paper is not to replace current management history documents but to provide complementary tables of cited regulations.

We queried a prototype of the database for records related to Caribbean Spiny Lobster. The records associated with bag limits, size limits, prohibited gear, and closures were reviewed and are summarized here.

Table 1. Recreational bag limit regulations contained within the Management History Database for Caribbean Spiny Lobster.

Region Affected	Fishery	Start Year	Effective Date	End Date	Bag Limit	FR Reference(s)	Amendment Number or Rule Type
Caribbean	Recreational	2012	01/30/2012	Ongoing	3 per person per day	76 FR 82413	Final Amendment 5
		2012	01/30/2012	Ongoing	10 per vessel per day	76 FR 82413	Final Amendment 5

Table 2. Size limit regulations for the commercial fishery and recreational and commercial fisheries combined (All) contained within the Management History Database for Caribbean Spiny Lobster.

Region Affected	Fishery	Start Year	Effective Date	End Date	Size Limit	Length Type	FR Reference(s)	Amendment Number or Rule Type
Caribbean	All	1985	01/01/1985	Ongoing	3.5 inches ¹	Minimum Carapace Length	49 FR 50049	Final Original FMP
Caribbean	Commercial	2009	02/11/2009	Ongoing	6 ounce ²	Tail Weight	74 FR 1148	Final Amendment 4

¹Size limit applies to non-egg-bearing spiny lobster

²Size limit applies to imported spiny lobster

Table 3. Gear restrictions for commercial and commercial and recreational fisheries combined (All) contained within the Management History Database for Caribbean Spiny Lobster.

Region Affected	Fishery	Gear Type	Start Year	Effective Date	End Date	Gear/Harvesting Restrictions	FR Reference(s)	Amendment Number or Rule Type
Caribbean	All	All	2005	11/28/2005	Ongoing	Prohibited fileting fish at sea	70 FR 62073	Final
						Reef fish vessels required to recover anchor by its crown		
		Explosives	1985	01/01/1985	Ongoing	Prohibited for spiny lobster	49 FR 50049	Final Original FMP
		Gillnets or Trammel Nets	2005	11/28/2005	Ongoing	Prohibit gillnets or trammel net for reef species ¹	70 FR 62073	Final Amendment 2
		Hookah ²	1997	01/13/1997	Ongoing	Prohibited hookah gear for harvesting conch	61 FR 65481	Final Original FMP
		Poison	1985	01/01/1985	Ongoing	Prohibited for spiny lobster	49 FR 50049	Final Original FMP
		Pots and Traps	1985	01/01/1985	09/19/1991	Include one degradable panel and/or door	49 FR 50049	Final Original FMP
			1986	09/22/1986	09/13/1991	Minimum mesh size 1 ¼”	50 FR 34850	Final Original FMP
			1991	09/14/1991	Ongoing	Minimum mesh size 2”	55 FR 46214	Final Amendment 1

Region Affected	Fishery	Gear Type	Start Year	Effective Date	End Date	Gear/Harvesting Restrictions	FR Reference(s)	Amendment Number or Rule Type
	All	Pots and Traps	1991	09/20/1991	11/14/1993	Include two degradable panels on opposite sides	56 FR 48755	Final
			1993	11/15/1993	11/27/2005	Include two degradable panels (sides no longer specified)	58 FR 53145	Final Amendment 2
			2005	11/28/2005	Ongoing	Include one degradable panel	70 FR 62073	Final
		Slurp Gun and Dip Nets	1993	11/15/1993	11/28/2005	Allow only slurp gun and hand-held dip nets for aquarium trade	58 FR 53145 70 FR 62073	Final Amendment 2 Final
		Spear	1985	01/01/1985	Ongoing	Prohibited for spiny lobster	49 FR 50049	Final Original FMP
	Commercial	Spear	2010	12/02/2010	Ongoing	Allow spear fishing for reef fish in the commercial sector	75 FR 67247	Final Regulatory Amendment
Caribbean Closed areas ³	All	Bottom gears ⁴	2005	11/28/2005	Ongoing	Prohibited year-round	70 FR 62073	Final
Caribbean Bajo de Sico	All	Anchoring	2010	12/02/2010	Ongoing	Anchoring by fishing vessels prohibited year-round	75 FR 67247	Final Regulatory Amendment

¹Gill nets and trammel nets used to fish other species must be tended at all times

²Lang Bank (St. Croix) only starting 11/28/2005

³Bajo de Sico, Abrir La Sierra, Tourmaline, Mutton Snapper Spawning Aggregation Area, Lang Bank, Hind Bank Marine Conservation District, and Grammanik Bank

⁴Pots, traps, bottom longlines, gillnets, trammel nets

Table 4. Closure regulations for Caribbean Spiny Lobster contained within the Management History Database.

Region Affected	Start Year	End Year	Start Day	End Day	Restriction During Closure	FR Reference(s)	Amendment Number or Rule Type
Caribbean Red Hind Spawning Aggregation West of Puerto Rico - Abrir La Sierra Bank	1996	1996	12/7	12/31	All fishing prohibited	61 FR 64485	Final Regulatory Amendment
	1997	Ongoing	1/1	2/28	All fishing prohibited	61 FR 64485	Final Regulatory Amendment
	1997	Ongoing	12/1	12/31	All fishing prohibited	61 FR 64485	Final Regulatory Amendment

Region Affected	Start Year	End Year	Start Day	End Day	Restriction During Closure	FR Reference(s)	Amendment Number or Rule Type
Caribbean Red Hind Spawning Aggregation West of Puerto Rico - Bajo De Sico	1996	1996	12/7	12/31	All fishing prohibited	61 FR 64485	Final Regulatory Amendment
	1997	2010	1/1	2/28	All fishing prohibited	61 FR 64485	Final Regulatory Amendment
	1997	2009	12/1	12/31	All fishing prohibited	61 FR 64485	Final Regulatory Amendment
	2010	2010	12/2	12/31	Fishing for reef fish prohibited	75 FR 67247	Final Regulatory Amendment

Region Affected	Start Year	End Year	Start Day	End Day	Restriction During Closure	FR Reference(s)	Amendment Number or Rule Type
Caribbean Red Hind Spawning Aggregation West of Puerto Rico - Bajo De Sico	2011	Ongoing	1/1	3/31	Fishing for reef fish prohibited	75 FR 67247	Final Regulatory Amendment
	2011	Ongoing	10/1	12/31	Fishing for reef fish prohibited	75 FR 67247	Final Regulatory Amendment
Caribbean Grammanik Bank Reef Fish Fishery Management Area	2005	Ongoing	2/1	4/30	All fishing prohibited	70 FR 62073	Final Amendment 2
Caribbean Hind Bank Marine Conservation District (MCD) Reef Fish Fishery Management Area	1989	1989	12/6	12/31	All fishing prohibited	54 FR 50624	Emergency Interim Rule

Region Affected	Start Year	End Year	Start Day	End Day	Restriction During Closure	FR Reference(s)	Amendment Number or Rule Type
Caribbean Hind Bank Marine Conservation District (MCD) Reef Fish Fishery Management Area	1990	1999	1/1	2/28	All fishing prohibited	54 FR 50624	Emergency Interim Rule
	1990	1999	12/1	12/31	All fishing prohibited	55 FR 46214	Final Amendment 1
	2000	Ongoing	1/1	12/31	All fishing prohibited	64 FR 60132	Final
Caribbean Mutton Snapper Spawning Aggregation Reef Fish Fishery Management Area	1994	Ongoing	3/1	6/30	All fishing prohibited	58 FR 53145	Final Amendment 2
Caribbean Red Hind Spawning Aggregation East of St. Croix Reef Fish Fishery Management Area	1993	Ongoing	12/1	12/31	All fishing prohibited	58 FR 53145	Final Amendment 2

Region Affected	Start Year	End Year	Start Day	End Day	Restriction During Closure	FR Reference(s)	Amendment Number or Rule Type
Caribbean Red Hind Spawning Aggregation East of St. Croix Reef Fish Fishery Management Area	1994	Ongoing	1/1	2/28	All fishing prohibited	58 FR 53145	Final Amendment 2
Caribbean Red Hind Spawning Aggregation West of Puerto Rico - Tourmaline Bank	1993	Ongoing	12/1	12/31	All fishing prohibited	58 FR 53145	Final Amendment 2
	1994	Ongoing	1/1	2/28	All fishing prohibited	58 FR 53145	Final Amendment 2
Caribbean St. Croix Management Area	2013	2013	12/19	12/31	All fishing prohibited	78 FR 18247	Temporary Rule Accountability Measure
	2016	2016	12/10	12/31	All fishing prohibited	81 FR 34283	Temporary Rule Closure
Caribbean Puerto Rico Management Area	2017	2017	9/7	9/30	All fishing prohibited	82 FR 31489	Temporary Rule Closure
	2021	2021	8/22	9/30	All fishing prohibited	86 FR 40787	Temporary Rule Closure
	2022	2022	7/12	9/30	All fishing prohibited	87 FR 38008	Temporary Rule Closure

3 ASSESSMENT HISTORY AND REVIEW

Previous stock assessments for US Caribbean spiny lobster have attempted to quantify stock status using both traditional as well as data-limited stock assessment procedures. Morris et al. (2004) and also SEDAR (2005A) provide assessment histories that summarize various traditional assessments; e.g., stock production analyses (ASPIC), CPUE examinations, yield per recruit, landings and length frequency. During SEDAR 46, a data-limited management strategy evaluation was conducted to simulation-test mean-length, indicator-based control rules (2016). A table of past assessment model applications can be found in the SEDAR 57 Final Stock Assessment Report (2019). SEDAR 57 was the first application of Stock Synthesis 3.0 (SS3) in the US Caribbean (2019). During SEDAR 57, the Puerto Rico spiny lobster stock assessment models were subject to numerous sensitivity analyses including assumptions related to natural mortality, growth, and selectivity (SEDAR, 2019). The Puerto Rico assessment models developed during SEDAR 57 were fit to catch time series and length composition information from dive and pot/trap fisheries; this is considered a data-limited to moderate implementation of SS3. SEDAR 57 resulted in a satisfactory stock status determination for providing management advice (2019). A data-only update was conducted in 2022 to provide ABCs and ACLs through May, 2025. Two new data streams became available during the SEDAR 91 Data Workshop: length compositions obtained from SEAMAP-C dive surveys conducted off of the Southwest Puerto Rico coast during 2021-2023 (ref), and length compositions obtained from an HJR Reefscaping lobster trap survey conducted throughout Puerto Rico coastal waters during 2021-2022. The Assessment Panel recommended fitting the SEDAR 91 Puerto Rico stock assessment to both of these data streams.

REGIONAL MAPS

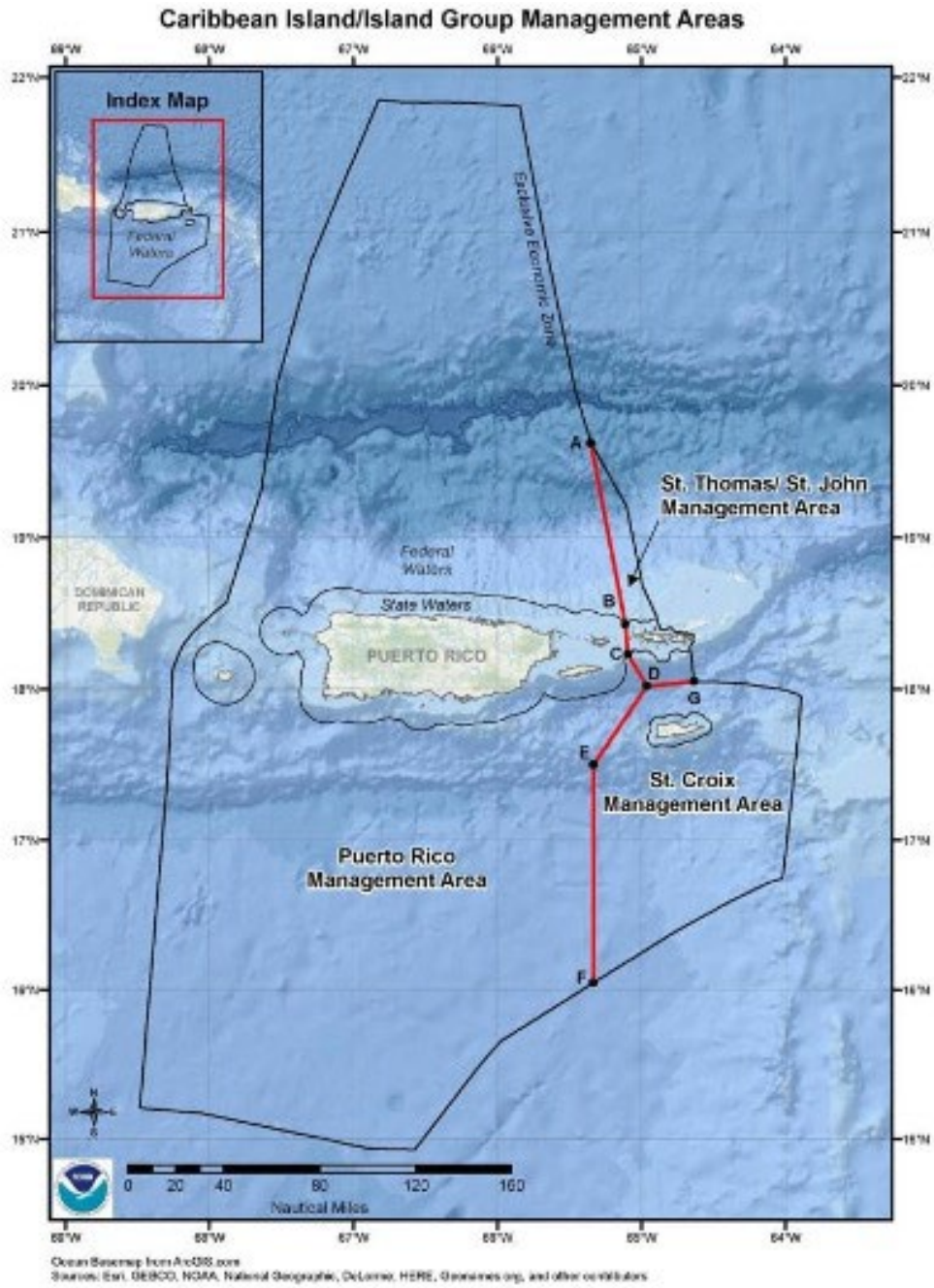


Figure 4.1 Jurisdictional boundaries of the Caribbean Fishery Management Council.

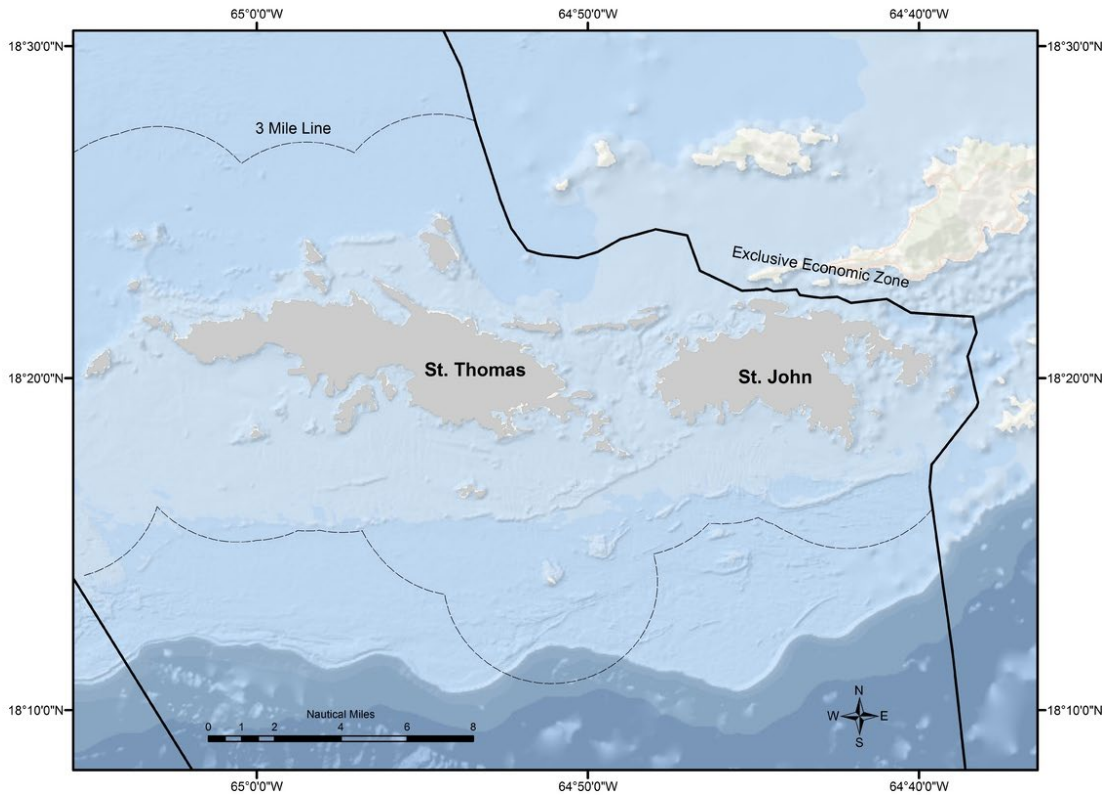


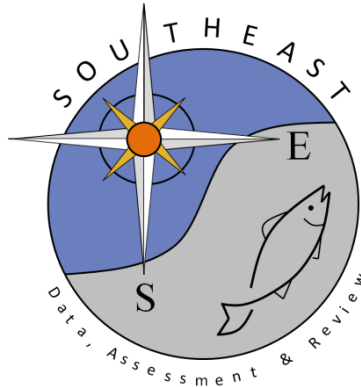
Figure 4.2: The U.S. Exclusive Economic Zone is defined as the federal waters ranging from 3 to 200 nautical miles (5.6 – 370 kilometers) from the nearest coastline point of the US Virgin Islands.

4 SEDAR ABBREVIATIONS

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder (software program)
ALS	Accumulated Landings System: SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
B	Biomass (stock) level
BAM	Beaufort Assessment Model
B _{msy}	B capable of producing MSY on a continuing basis
BSIA	Best Scientific Information Available
CHTS	Coastal Household Telephone Survey

CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
F	Fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	F to produce MSY under equilibrium conditions
F_{OY}	F rate to produce OY under equilibrium
$F_{XX\% SPR}$	F rate resulting in retaining XX% of the maximum spawning production under equilibrium conditions
F_{max}	F maximizing the average weight yield per fish recruited to the fishery
F_o	F close to, but slightly less than, F_{max}
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	General Linear Model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MARFIN	Marine Fisheries Initiative
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	Maximum Fishing Mortality Threshold: value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey: combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSA	Magnuson Stevens Act
MSST	Minimum Stock Size Threshold: value of B below which the stock is deemed to be overfished
MSY	Maximum Sustainable Yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OST	Office of Science and Technology, NOAA

OY	Optimum Yield
SAFMC	South Atlantic Fishery Management Council
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Southeast Fisheries Science Center, NMFS
SERFS	Southeast Reef Fish Survey
SERO	Southeast Regional Office, NMFS
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	Spawning Potential Ratio: B relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Scientific and Statistical Committee
TIP	Trip Interview Program: biological data collection program of the SEFSC and Southeast States
TPWD	Texas Parks and Wildlife Department
Z	total mortality (M+F)



SEDAR

Southeast Data, Assessment, and Review

SEDAR 91

US Caribbean Spiny Lobster Puerto Rico

SECTION II: Data Workshop Report

January 2025

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1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 91 Data Workshop was held November 13-15, 2024, in St Thomas, USVI. In addition to the in-person workshop, a series for webinars were held before (June and October 2024) the meeting.

1.2 TERMS OF REFERENCE

Data Workshop Terms of Reference:

1. Review available data inputs and provide tables and figures including, but not limited to:
 - a. Commercial and recreational catches and/or discards.
 - b. Length/age composition data
 - c. Life history and ecological information
 - d. Indices of abundance
 - e. Include data through at least 2022.
2. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on research goals, data to be collected, and how the research will inform stock assessment.
3. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II of the SEDAR assessment report).

1.3 LIST OF PARTICIPANTS

Data Workshop Participants

Matt Damiano (Lead Analyst).....	NMFS/SEFSC
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Sarah Beggerly.....	NMFS/SEFSC
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Jorge R. Garcíá	CFMC SSC
Katherine Godwin.....	UM-CIMAS
Sennai Habtes	USVI DPNR
Daniel Matos-Caraballo	PR DNER
Kevin McCarthy	NMFS/SEFSC
Maggie Rios.....	USVI DPNR
M. Refik Orhun.....	NMFS/SEFSC
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 Jesus Leon
 Martha Prada..... DRNA
 Vanessa Ramirez.....
 Noemi Peña AlvardPR DNER
 Aida Rosario.....PR DNER

1.4 LIST OF DATA WORKSHOP WORKING PAPERS & REFERENCE DOCUMENTS

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data Workshop			
SEDAR91-DW-01	Summary of participatory modeling workshops to understand ecological, social and economic dimensions of the U.S. Virgin Islands lobster fishery	Juan Agar, Mandy Karnauskas, Kelsi Furman, Matt McPherson, Manoj Shivlani	11/1/2024
SEDAR91-DW-02	Summary of participatory modeling workshops to understand ecological, social and economic dimensions of the Puerto Rican lobster fishery	Mandy Karnauskas, Juan Agar, Matt McPherson, Kelsi Furman, Manoj Shivlani	11/1/2024
SEDAR91-DW-03	PR/DNER/Commercial Fisheries Statistics Program Report Signs of the Abundance of Spiny Lobster <i>Panulirus argus</i> Observed by Commercial Landings Reported during 2014-2023	Daniel Matos-Caraballo, Jesús León-Fernández, Luis A. Rivera-Padilla, and Wilson Santiago-Soler	11/15/2024
SEDAR91-DW-04	SEDAR 91 Trip Interview Program (TIP) Size Composition Analysis of Caribbean Spiny Lobster (<i>Panulirus argus</i>) in Puerto Rico, U.S. Caribbean, 1981-2023	Katherine Godwin, Adyan Rios	11/20/2024
SEDAR91-DW-05	SEDAR 91 Trip Interview Program (TIP) Size Composition Analysis of Caribbean Spiny Lobster (<i>Panulirus argus</i>) in St. Thomas/St. John, U.S. Caribbean, 1981-2023	Katherine Godwin, Adyan Rios	11/20/2024
SEDAR91-DW-06	SEDAR 91 Trip Interview Program (TIP) Size Composition Analysis of Caribbean Spiny Lobster (<i>Panulirus argus</i>) in St. Croix, U.S. Caribbean, 1981-2023	Katherine Godwin, Adyan Rios	11/20/2024
SEDAR91-DW-07	SEDAR 91 Commercial Landings of Caribbean Spiny Lobster (<i>Panulirus argus</i> , <i>Panulirus guttatus</i>)	M. Refik Orhun, Katherine Godwin, Kim Johnson, and	11/24/2024

	in Puerto Rico, US Caribbean, 1983-2023	Stephanie Martínez Rivera	
SEDAR91-DW-08	SEDAR 91 Commercial Landings of Caribbean Spiny Lobster (<i>Panulirus argus</i>) in St. Thomas and St. John, US Caribbean, 1975-2023	M. Refik Orhun, Katherine Godwin, Kim Johnson, and Stephanie Martínez Rivera	11/24/2024
SEDAR91-DW-09	SEDAR 91 Commercial Landings of Caribbean Spiny Lobster (<i>Panulirus argus</i>) in St. Croix, US Caribbean, 1975-2023	M. Refik Orhun, Katherine Godwin, Kim Johnson, and Stephanie Martínez Rivera	11/24/2024
Reference Documents			
SEDAR91-RD01	On the productivity and technical efficiency of the Puerto Rican queen conch <i>Aliger gigas</i> fishery	Juan Agar and Daniel Solis	10/9/2024
SEDAR91-RD02	Socio-economic Profile of the Small-scale Dive Fishery in the Commonwealth of Puerto Rico	Juan J. Agar and Manoj Shivlani	10/9/2024
SEDAR91-RD03	Determining the age-size relationship of <i>Panulirus argus</i> in the southwest area of Puerto Rico	Ana G. Medina Martinez	10/9/2024
SEDAR91-RD04	Annual Juvenile Recruitment of Spiny Lobsters, <i>Panulirus Argus</i> (Decapoda, Palinuridae), in a Shallow Seagrass Bed and a Deeper Hard Bottom off Western Puerto Rico	Nilda M. Jiménez, Ernest H. Williams, Jr. and Aida Rosario	10/10/2024
SEDAR91-RD05	Patterns of Spiny Lobster (<i>Panulirus argus</i>) Postlarval Recruitment in the Caribbean: A CRTR Project	Mark J. Butler IV, Angela M. Mojica, Eloy Sosa-Cordero, Marines Millet and Paul Sanchez-Navarro	10/10/2024
SEDAR91-RD06	Developing a population assessment for Caribbean spiny lobster <i>Panulirus argus</i> in the United States Virgin Islands: lessons learned	Lee Richter ¹ and Michael W Feeley ²	11/7/2024
SEDAR91-RD07	Estimate of In-water Size Structure of Spiny Lobsters in St. Thomas	Tyler B. Smith, Sarah L. Heidmann, Rosmin S. Ennis, Viktor W. Brandtneris,	11/7/2024

		Adeline Shelby, Jeremiah Blondeau	
SEDAR91- RD08	Displaced juvenile and subadult Caribbean spiny lobsters show strong orientation toward home dens	Michael J. Childress a,* Coral Holt a, Rodney D. Bertelsen b	11/14/2024
SEDAR91- RD09	Ocean acidification disrupts the orientation of postlarval Caribbean spiny lobsters	Philip M. Gravinese, Heather N. Pag, Casey B. Butler, Angelo Jason Spadaro, Clay Hewett, Megan Considine, David Lankes & Samantha Fisher	11/14/2024
SEDAR91- RD10	Relationships between postlarval settlement and commercial landings of Caribbean spiny lobster (<i>Panulirus argus</i>) in Florida (USA)	Emily Hutchinson, Thomas R. Matthews , Gabrielle F. Renchen	11/14/2024
SEDAR91- RD11	Gastric mill ossicles record chronological age in the Caribbean spiny lobster (<i>Panulirus argus</i>)	Emily Hutchinson, Thomas. R Matthews, Erica Ross, Samantha Hagedorn , Mark J. Butler IV,	11/14/2024
SEDAR91-12	Spiny Lobster SEAMAP Program Survey 2021-23	Department of Natural and Environmental Resources	11/14/2024
SEDAR91-13	Progress Report: Independent fishery data collection for lobster (<i>Panulirus argus</i>) and conch (<i>Lobatus gigas</i>) under the SEAMAP-C program	Juan J. Cruz Motta	11/14/2024

2. Life History

2.1 Overview

No new life history information was available for the SEDAR Panel to discuss during the data workshop. Therefore, sections 2.2-2.8 were carried over from SEDAR 57.

2.2 Stock Definition and Description

The Caribbean spiny lobster, *Panulirus argus* (hereafter referred to as spiny lobster), occurs in the Caribbean Sea, the Gulf of Mexico and the Western Central and South Atlantic Ocean. North Carolina marks its northernmost limit whereas Brazil marks its southernmost limit (Bliss 1982). The spiny lobster occurs from the extreme shallows of the littoral fringe to depths exceeding 100 meters (Kanciruk 1980; Munro 1974). CFMC (1981) reports that its distribution off Puerto Rico extends to the edge of the shelf, which is described as the 100–fathom contour (183 meters). Shallow areas with mangroves and seagrass (*Thalassia testudinum*) beds serve as nursery areas where available (Munro 1974). Generally, spiny lobsters move offshore when they reach reproductive size (Phillips et al. 1980). These animals are primarily carnivores, and serve as the major benthic carnivores in some ecosystems (Kanciruk 1980), feeding upon smaller crustaceans, mollusks and annelids (Cobb and Wang 1985).

2.3 Meristic & Conversion factors

Length-weight conversions were estimated using the Trip Interview Program (TIP) database. TIP records were filtered according to island platform (Puerto Rico, St. Thomas/St. John, and St. Croix). Records were further filtered such that retained records consisted only of those with paired length-weight measurements that had reported units of measure (e.g., mm or kg) and corresponding measurement type (e.g., carapace length or whole weight). A subsequent evaluation of data entry and/or measurement errors led to the removal of 33 records for Puerto Rico (Table 2.1.)

Length-weight (L-W) relationships were fit as log-linear functions in the R statistical computing software (Quinn and Deriso 1999, R Development Core Team 2012). The relationship for cephalothorax length (CL; mm) to weight (kg whole weight) is:

$$W = aL^b$$

Model fitting was carried out using linear regression on the log transformed equation:

$$\log(W) = \log(a) + b * \log(L)$$

Resulting L-W relationships are found in Table 2.2. For Puerto Rico, a total of $n=22,980$ L-W observations were available from TIP (n male=12,019; n female=10,961) from 1980 to 2016 (Fig. 2.1). The largest individual by length was 196 mm CL, which was also the largest individual by weight (4.536 kg). Cephalothorax length to weight conversions by Island Platform are shown in Table 2.2.

Spatial analysis of Puerto Rico L-W data according to four Caribbean spatial areas suggested that L-W curves were not significantly different (p-value = 1.0; Table 2.3).

2.4 Natural Mortality

During SEDAR 8, various sources are referenced with respect to natural mortality, including Olsen and Koblic 1975, Medley and Ninnes 1996, and FAO 2001. Natural mortality was specified at 0.36 for adult lobsters and used for all ages during SEDAR 8. During SEDAR 46 (Spiny lobster St. Thomas/St. John and St. Croix), consideration was given to natural mortality estimates from tagging studies, with estimates typically varying between 0.26 and 0.44 year⁻¹ for adult spiny lobster, with the most reliable estimates suggested to be in the range of 0.30 to 0.40 (FAO 2001). A point estimate of 0.34 year⁻¹, calculated from a variant of Pauly's equation, is also widely reported (Cruz et al. 1981). Point estimates based on longevity were also considered, but require evidence of maximum age, which is difficult to obtain for lobsters (Kanciruk 1980). This issue is reinforced by additional statements made by Olsen and Koblic (1975). Further discussion about spiny lobster longevity can be found on pg 27, SEDAR 46, Data and Assessment Workshop report (SEDAR 2016). Several spiny lobster stock assessments in the Caribbean have used 0.34 to 0.36 year⁻¹ in base model runs (Cruz 2001; Gongora 2010; SEDAR 2005; Babcock et al. 2014). During the SEDAR 57 data workshop, participants identified a mark-recapture dataset from a study undertaken by the St. Thomas Fishermen's Association (Olsen et al. 2017). Analysts determined obtaining an estimate of natural mortality from this study for use in the assessment was not feasible; this was potentially due to an underestimate of reporting practices stated by Olsen et al. (2017), which resulted in an unreasonably high ($M > 2.0$ year⁻¹) estimates of natural mortality (see SEDAR 57 Final Assessment Report).

2.5 Reproduction

Die (2005) estimated a logistic maturity curve from TIP prior to 1990, when landing of egg bearing females was permitted. Data from Puerto Rico and St. Thomas/St. John were aggregated for the purpose of model fitting. Two model parameterizations were considered, in both cases, length at 50% maturity were similar being either 91 mm or 92 mm CL.

For SEDAR 8 (2005), fecundity-at-length was obtained for Cuba spiny lobster (FAO 2001):

$$E = 0.5911L^{4.5677},$$

where E is number of eggs and L is carapace length in mm.

2.6 Age and Growth

During SEDAR 8, von Bertalanffy growth curves for males and females were obtained from Leon et al. (1994) for Cuba (SEDAR 2005). Since SEDAR 8, several additional publications have become available for von Bertalanffy growth curves from regions such as Cuba, Puerto Rico, and Mexico (Table 2.3). Also, during SEDAR 46 (Spiny lobster St. Thomas/St. John & St. Croix), von Bertalanffy growth parameters from Leon et al. (1995) were reviewed, noting similar values used in other stock assessment (i.e., Gongora 2010; Babcock et al. 2014). These point estimates were also compared to a more recent study by Leon et al. (2005) and analyses in SEDAR 46 were based on a single growth curve for both sexes. During the SEDAR 57 data

workshop, participants identified a mark-recapture dataset from a study undertaken by the St. Thomas Fishermen’s Association (Olsen et al. 2017). During SEDAR 57, analysts determined that obtaining a growth curve from this study for use in the assessment was not feasible. This was due to an absence of the largest size classes in the data set, though results verified that growth in Puerto Rico (Table 2.3) was generally consistent with growth in St. Thomas/St. John (see SEDAR 57 Final Assessment Report).

Table 2.1 Records manually removed from Puerto Rico TIP prior to CL-W model fitting.

CL	W	Sex	CL	W	Sex
267	0.42	F	209	0.907	M
325	0.582	F	340	0.67	M
340	0.846	F	340	0.498	M
342	0.7	F	300	0.38	M
899	0.564	F	310	0.552	M
162	30.6	F	514	0.83	M
94	7.681	F	275	0.364	M
100	9.481	F	290	0.442	M
90	6.116	F	262	0.33	M
20.574	0.467	F	202	1.03	M
10	0.531	F	814	0.814	M
10	0.849	F	952	0.64	M
			123	11.4	M
			101	8.871	M
			1	1.142	M
			20.574	0.56	M
			20.32	0.506	M
			20.574	0.59	M
			20.574	0.682	M
			60.7	4.075	M
			192	0.68	M

Table 2.2 Fitted conversion functions from cephalothorax length (mm) to weight (kg whole weight) for Puerto Rico.

Island platform	Year	n	a	b
Puerto Rico				
Males	1980-2016	12,019	6.836E-05	2.536
Females	1980-2016	10,961	7.612E-05	2.521
Males + Females	1980-2016	22,980	4.166E-05	2.511

Table 2.3 von Bertalanffy growth parameters, noting values used in SEDARs 8 and 46 (i.e., Leon et al. (1995)) and with emphasis on subsequent studies.

Study	Region/Country	Source	Sex	CL ∞ (mm)	K
Leon et al. (1995)	Cuba	Length frequency	M	184	0.24
			F	155	0.22
Leon et al. (2005)	Cuba	Length frequency	Both	184	0.24
Mateo (2004)	Puerto Rico	Length frequency	M (1999)	197	0.24
			M (2000)	195	0.24
			F (1999)	191	0.25
			F (2000)	185	0.23
Velazquez- Abunader et al. (2015)	Mexico, Yucatan	Length frequency	M	203	0.28
			F	189	0.34

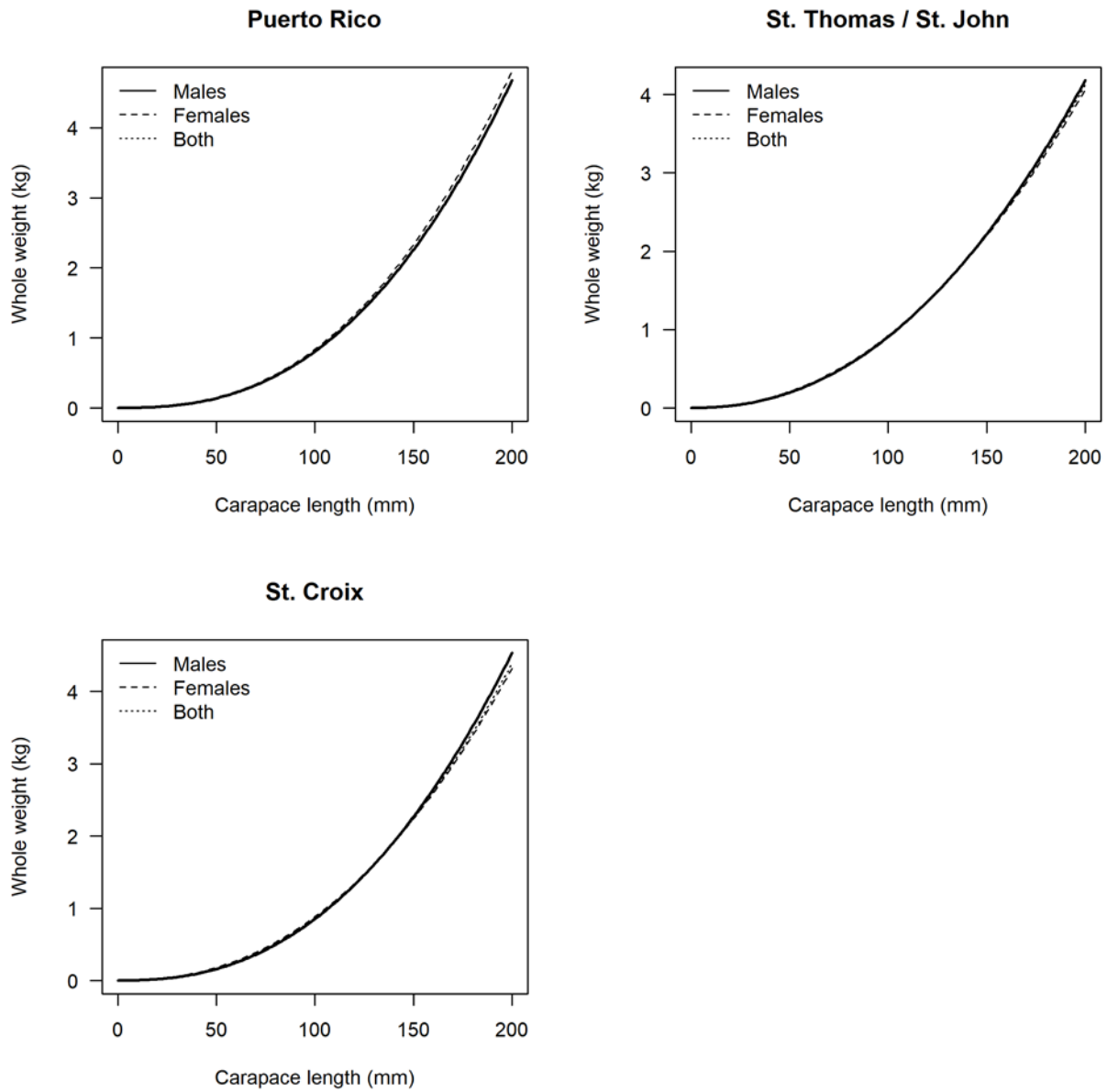


Figure 2.1 Length-weight curves for spiny lobster of Puerto Rico, St. Thomas/St. John, and St. Croix.

3. Commercial Fishery Statistics

3.1 Biological Sampling

3.1.1 Overview

The NOAA Fisheries, Southeast Fisheries Science Center Trip Interview Program (TIP) collects length and weight data from fish landed by commercial fishing vessels, along with information about fishing area and gear. Data collection began in the 1980s with frequent updates in best practices; the latest being in 2017. Data are collected by trained shore-based samplers (Beggerly et al., 2022).

3.1.2 Length Composition Sampling Intensity

The TIP data pertaining to Caribbean Spiny Lobster in Puerto Rico consists of 69,212 length observations across 7,894 unique port sampling interviews (Figure 3.1.1). Of the Caribbean spiny lobster measured, 69,065 were CL observations (99.8%). Plots and summary statistics of the currently available CL frequency data of Caribbean spiny lobster sampled from the predominant gears in Puerto Rico are included in the working paper (Godwin et al. 2024).

3.1.3 Length Distributions

A variety of fishing gears were used by Puerto Rico commercial fishers to catch Caribbean spiny lobster. A generalized linear mixed model (GLMM) was fit to TIP data to compare mean CL composition among gear types. The purpose of the analysis was to identify gear groups among the commercial fishing gears with groups based upon Caribbean spiny lobster size composition. Gears with size compositions that were not significantly different were assigned to the same gear group. The analysis identified no difference in mean size composition among gear specific size compositions and the gears with confidential data are provided in Table 3.1.1. Summary statistics produced by the GLMM analysis of the available length frequency data from 1981 to 2023 are also included in Table 3.1.1. Gear groups were identified based on GLMM analysis using a gamma-distributed dependent variable and a covariate to account for changes in mean CL over time. Random effects for interview ID and categorical year were included to account for non-independence of observations.

The aggregated density plot for all gears combined of Caribbean spiny lobster CL collected across the time series 1981-2023 are summarized in Figure 3.1.2. Aggregated density plots of Caribbean spiny lobster landed by nonconfidential gears are summarized in Figure 3.1.3.

3.1.4 Adequacy of Size Composition Data for Characterizing Catch

Due to reasonable levels of available data throughout the time series, TIP data can be considered to inform selectivity and annual population trends in the SEDAR 91 assessment. A weight-length analysis was not conducted to identify outliers in the TIP data. A cutoff of 2.5cm minimum and 25cm maximum CL was implemented to remove notable outliers in the TIP dataset (Godwin et al 2024).

Decisions:

- Consider TIP data to inform selectivity and annual population trends in the SEDAR 91 assessment.
- Compare SEAMAP-C data and data from two pilot studies (MER Consultants at sea size composition and HJR Reefscaping at sea CL composition studies) with TIP data.
- Supply complete TIP time series for use in SEDAR 91 analyses.

3.2 Commercial Landings

3.2.1 Overview

Commercial fishery landings in Puerto Rico, were obtained from self-reported fisher logbook data (Caribbean Commercial Logbook, CCL). Commercial fishery landings data for Caribbean Spiny Lobster in Puerto Rico were available for the years 1983-2023.

3.2.2 Outlier Analysis

An outlier analysis was conducted by using a mean and standard deviation method. If the landings of Caribbean Spiny Lobster reported on a trip were greater than three standard deviations from the mean (i.e., 99.73% quantile), they were marked for removal from the dataset. Outliers were identified for each gear group across all years. Total landings with and without outliers are shown in Figure 3.2.1 and the percent change in landings with outliers removed is shown in Table 3.2.1.

Decisions:

- SEDAR 91 Panel decided to define as outliers trips with landings of 1,000 pounds or more. Reports from those trips should be investigated and if found errant, remove them from the commercial landings' series for Puerto Rico.
- The panel recommended that the lead analyst be given the freedom to explore the assessment start year, tentatively recommending 1985. Members of the panel suggested that landings reported prior to 1985 may have included catches from outside of Puerto Rico's EEZ.

3.2.3 Adoption (partial) of Electronic Reporting Since 2020

Starting in 2020, commercial fishers have had an electronic reporting option for reporting landings on their fishing trips. According to DRNA the adoption rate of electronic reporting is estimated to be around 40%. Due to differences in variable names and other database issues, integration of those electronically reported data into the CCL, and ultimately the Accumulated Landing System (ALS), has been difficult and has necessitated many labor-intensive adjustments to integrate these to the landings datasets for each year since its adoption.

3.2.4 Expansion Factors and Calculation of Commercial Landings

Expansion factors to account for known underreporting and to better estimate commercial landings in Puerto Rico have been in use since landings data collection began in 1983. Port samplers go to a fishing landings center and record the landings of all vessels at that location.

The port sampler observed landings at each location/day are compared to the commercial logbooks with reported landings at the same location/day combination. The ratio of reported landings to observed landings, across all locations within a coast (as defined by DRNA) is the expansion factor for that coast. Expansion factors are not species specific. Expansion factors are usually smaller than 1, meaning not all landings observed by port agents are reported by the fisher:

$$\text{Expansion Factor} = \text{Sum of Reported Landings} / \text{Sum of Observed Landing}$$

The landings are then expanded by the inverse of the expansion factor (aka the expansion factor):

$$\text{Expansion Factor} = 1 / \text{Expansion Factor}$$

From 1983 to 2002, one expansion factor was used for all of Puerto Rico to expand the reported commercial landings. Starting in 2003 expansion factors by coast were adopted; i.e., separate expansion factors estimated and used for North, East, South and West Coast, Figure 3.2.2 shows Municipalities of Puerto Rico. A more detailed map of the municipalities and Fishing Landings Centers is shown in Appendix 1.

Since the beginning of electronic reporting, data accessibility, and calculation of expansion factors has been challenging. To provide expansion factors for the years 2020-23 (years of electronic reporting), the mean coast specific expansion factors calculated over the years 2014-2019 were used to calculate the expanded landings.

3.2.5 Puerto Rico Caribbean Spiny Lobster Fishery

Commercial fishery landings in Puerto Rico were obtained from self-reported fisher logbook data (Caribbean Commercial Logbook, CCL) that are mailed or delivered to the Puerto Rico Department of Natural and Environmental Resources (DNER or DRNA in Spanish). Commercial landings were reported by species, fishing gear, and the fishing center where the catch was landed.

Commercial fishery landings data for Caribbean Spiny Lobster in Puerto Rico were available for the years 1983-2023. The gear grouping followed the recommendations of the prior Caribbean Spiny Lobster assessment and its update (SEDAR 57, 2019; SEDAR 57 Update, 2022) shown in Orhun et al. (2024) with the addition of “NETS” as separate gear group. The commercial landings were presented in pounds by year and fishing gear groups are shown in Table 3.2.2.

Decision:

- The SEDAR 91 panel decided to combine all net gears; i.e., cast net, gill net and trammel net as a separate “NETS” gear group. The panel also decided to give the lead analyst freedom to explore fleet structure in the assessment model.

3.3 Commercial Discards

Species-specific commercial discard reporting was not established in Puerto Rico for Caribbean Spiny Lobster during the period 1983-2023.

3.4 Commercial Effort

Commercial trips with reported Caribbean Spiny Lobster landings per year and gear group were compiled from 1983 to 2023 (Table 3.4.1).

Table 3.1.1 GLMM analysis summary results for Puerto Rico TIP Caribbean Spiny Lobster CL (cm) from 1981 to 2023. The column titled “group” indicates the group(s) where mean CL are not statistically different from other gears with matching group number(s). The “n” column indicates the number of unique lengths recorded for each gear. The “Percentage” column indicates the percent of the total recorded lengths for each gear. Only nonconfidential data shown.

Gear	Mean (cm)	Estimated Marginal Mean	LCL	UCL	Group	Lobster (n)	Interview (n)	Percentage
BY HAND; DIVING GEAR	10.14	2.30	2.30	2.31	1	48,772	5,977	71.59
POTS AND TRAPS; FISH	9.79	2.32	2.30	2.33	1	10,801	1,020	15.85
POTS AND TRAPS; SPINY LOBSTER	9.92	2.29	2.28	2.31	1	4,370	304	6.41
TRAMMEL NETS	10.21	2.31	2.29	2.32	1	1,775	221	2.61

Table 3.2.1 Comparison expanded landings before and after outlier removal of commercial landings of Caribbean Spiny Lobster in pounds for Puerto Rico.

Year	Expanded Landings (lbs.)	Expanded Landings outlier analysis (lbs.)	Difference (%)
1983	448,508	447,524	0.2
1984	420,343	418,530	0.4
1985	376,525	374,344	0.6
1986	279,757	260,191	7.0
1987	205,821	181,639	11.7
1988	252,020	240,642	4.5
1989	363,939	338,746	6.9
1990	329,415	302,116	8.3
1991	414,945	379,740	8.5
1992	268,317	237,424	11.5
1993	281,659	249,645	11.4
1994	300,095	286,801	4.4
1995	392,427	375,510	4.3
1996	392,777	371,898	5.3
1997	363,096	336,134	7.4
1998	381,511	339,054	11.1
1999	417,854	370,992	11.2
2000	449,641	415,172	7.7
2001	411,429	398,978	3.0
2002	349,237	313,213	10.3
2003	395,962	361,077	8.8
2004	476,493	471,092	1.1
2005	298,688	291,249	2.5
2006	276,402	271,272	1.9
2007	265,615	254,987	4.0
2008	330,029	294,887	10.6
2009	323,143	312,692	3.2
2010	289,630	264,583	8.6
2011	273,018	269,733	1.2
2012	384,059	378,357	1.5
2013	275,421	274,367	0.4
2014	296,806	293,023	1.3
2015	417,579	406,909	2.6
2016	445,733	434,089	2.6
2017	281,905	275,150	2.4
2018	518,331	496,520	4.2
2019	488,196	475,101	2.7
2020	298,750	292,654	2.0
2021	416,528	411,649	1.2
2022	534,147	499,588	6.5
2023	616,177	560,874	9.0
Total	15,001,928	14,228,146	5.2

Table 3.2.2 Commercial landings of Caribbean Spiny Lobster in pounds by gear group that reported Caribbean Spiny Lobster landings in Puerto Rico. ‘Expanded Lbs’ are the total landings of Caribbean Spiny Lobster in pounds estimated by applying the expansion factors.

*Data are not confidential.

YEAR	EXPANDED DIVING ALL LBS	EXPANDED NETS LBS	EXPANDED POTS AND TRAPS ALL LBS	EXPANDED TOTAL LBS
1983	411,599	207	36,702	448,508
1984	377,932	109	42,302	420,343
1985	135,604	11,271	229,650	376,525
1986	103,758	7,147	168,852	279,757
1987	63,963	3,942	137,916	205,821
1988	112,287	12,473	127,260	252,020
1989	132,658	13,485	217,796	363,939
1990	119,915	10,595	198,905	329,415
1991	157,496	31,938	225,511	414,945
1992	96,077	20,794	151,446	268,317
1993	122,488	22,096	137,075	281,659
1994	123,167	17,009	159,919	300,095
1995	165,732	32,725	193,970	392,427
1996	174,057	24,704	194,016	392,777
1997	151,841	26,728	184,527	363,096
1998	176,607	24,306	180,598	381,511
1999	169,835	33,766	214,253	417,854
2000	228,922	19,000	201,719	449,641
2001	200,313	11,377	199,739	411,429
2002	175,330	7,015	166,892	349,237
2003	162,356	27,797	205,809	395,962
2004	211,980	21,675	242,838	476,493
2005	135,117	9,094	154,477	298,688
2006	136,014	10,046	130,342	276,402
2007	153,650	8,168	103,797	265,615
2008	209,971	11,713	108,345	330,029
2009	199,276	6,323	117,544	323,143
2010	168,271	26,834	94,525	289,630
2011	172,693	3,942	96,383	273,018
2012	224,069	10,270	149,720	384,059
2013	177,514	15,684	82,223	275,421
2014	175,756	23,536	97,514	296,806
2015	236,900	22,221	158,458	417,579
2016	237,239	25,657	182,837	445,733
2017	163,971	14,150	103,784	281,905
2018	321,863	22,634	173,834	518,331
2019	279,995	29,248	178,953	488,196
2020	151,397	17,657	129,696	298,750
2021	222,740	16,936	176,852	416,528
2022	281,371	29,344	223,432	534,147
2023	354,023	32,621	229,533	616,177
Total	7,775,747	716,237	6,509,944	15,001,928

Table 3.4.1 Number of commercial trips reported by gear group that included Caribbean Spiny Lobster landings in Puerto Rico. *Data are not confidential.

YEAR	TRIPS DIVING	TRIPS NETS	TRIPS POTS AND TRAPS	TRIPS GRAND TOTAL
1983	23,265	37	1,128	24,430
1984	22,786	36	1,651	24,473
1985	6,626	840	11,718	19,184
1986	4,933	604	5,812	11,349
1987	2,834	305	4,898	8,037
1988	3,740	372	4,448	8,560
1989	3,507	294	6,273	10,074
1990	2,914	903	6,841	10,658
1991	4,971	1,138	8,824	14,933
1992	3,359	870	4,701	8,930
1993	4,866	1,222	5,400	11,488
1994	5,939	1,111	6,731	13,781
1995	8,744	1,607	10,996	21,347
1996	9,629	1,898	12,320	23,847
1997	8,756	1,647	9,522	19,925
1998	9,749	1,051	9,361	20,161
1999	10,216	1,667	11,708	23,591
2000	8,500	1,181	8,931	18,612
2001	9,158	1,042	8,672	18,872
2002	9,104	677	8,600	18,381
2003	5,319	607	4,732	10,658
2004	5,744	592	3,764	10,100
2005	5,166	414	3,063	8,643
2006	5,340	742	2,669	8,751
2007	5,544	522	1,934	8,000
2008	5,375	488	1,714	7,577
2009	5,856	293	2,218	8,367
2010	4,712	411	2,028	7,151
2011	6,872	237	2,062	9,171
2012	7,417	482	2,533	10,432
2013	8,191	712	2,276	11,179
2014	8,379	968	2,518	11,865
2015	8,253	909	2,976	12,138
2016	7,409	892	2,998	11,299
2017	5,217	536	1,872	7,625
2018	8,149	798	1,952	10,899
2019	8,665	933	2,718	12,316
2020	4,593	665	1,979	7,237
2021	6,716	635	2,425	9,776
2022	7,449	991	2,683	11,123
2023	8,448	855	2,575	11,878
Total	302,410	32,184	202,224	536,818

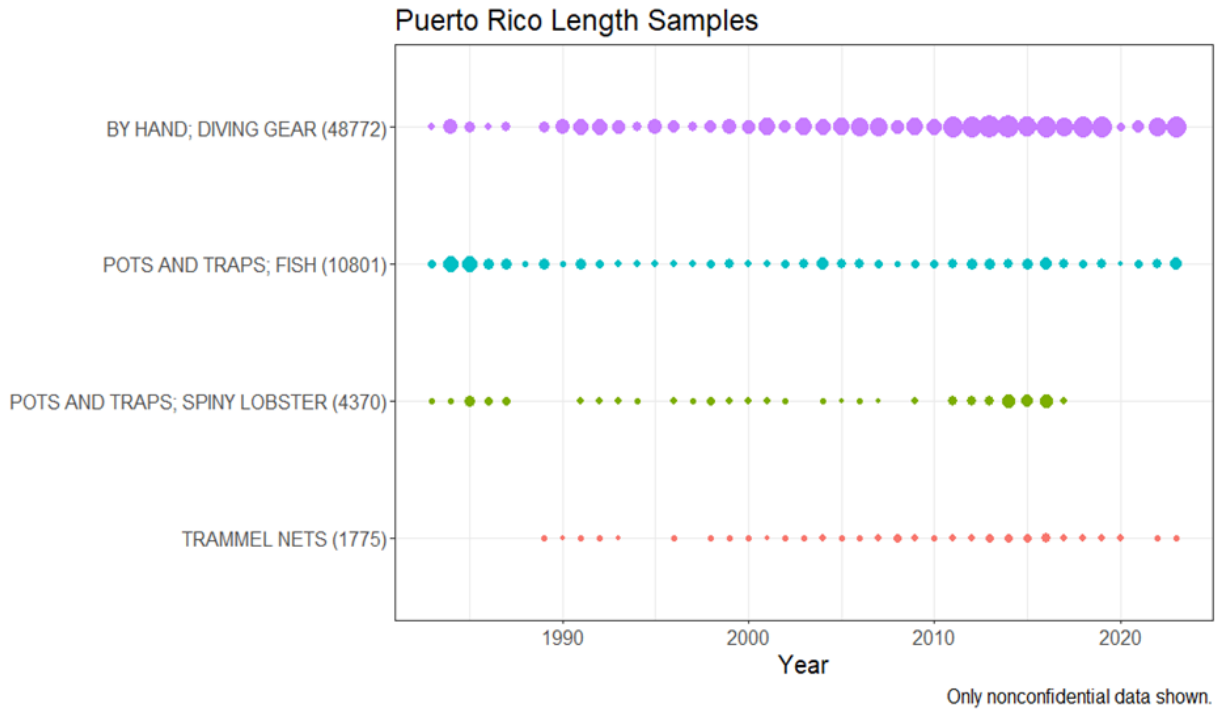


Figure 3.1.1 Plot showing relative number of Caribbean Spiny Lobster CL in Puerto Rico across time collected. Each point is color specific to the gear it represents. Gears are arranged from most to least abundant.

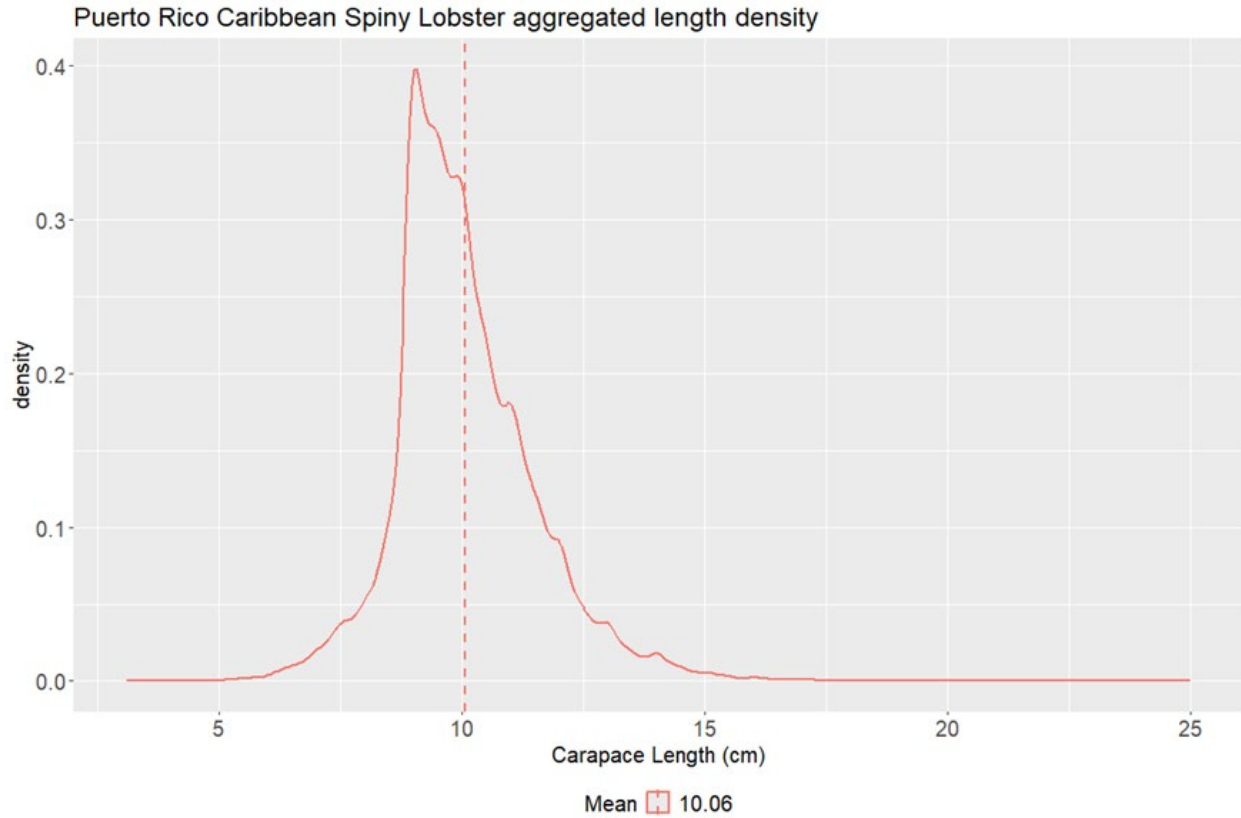


Figure 3.1.2 Aggregated density plot of cephalothorax lengths (cm) of Caribbean Spiny Lobster in Puerto Rico, all gears combined. Dotted line represents mean CL.

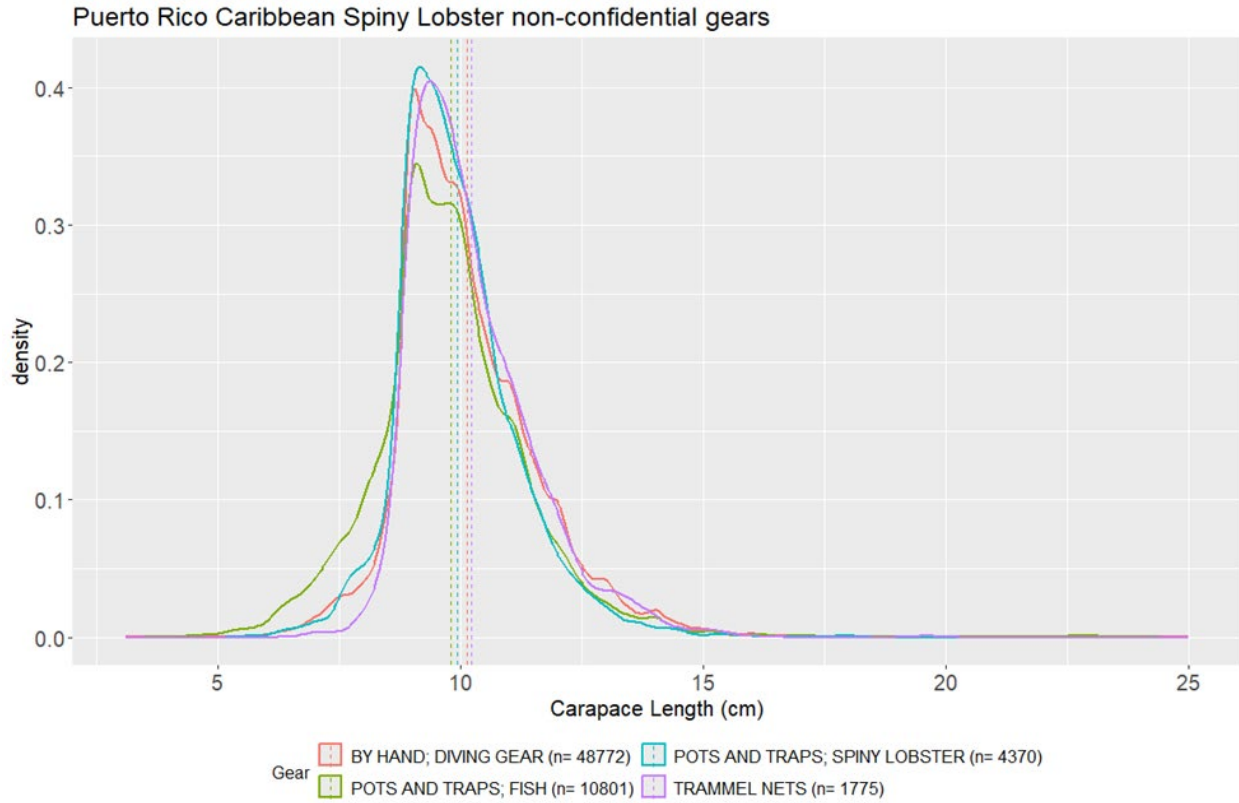


Figure 3.1.3 Aggregated density plot of cephalothorax length (cm) of nonconfidential gears recorded for Caribbean Spiny Lobster in Puerto Rico from 1981 to 2023. Dotted line represents mean CL. Mean lengths can be found in **Table 3.1.1**.

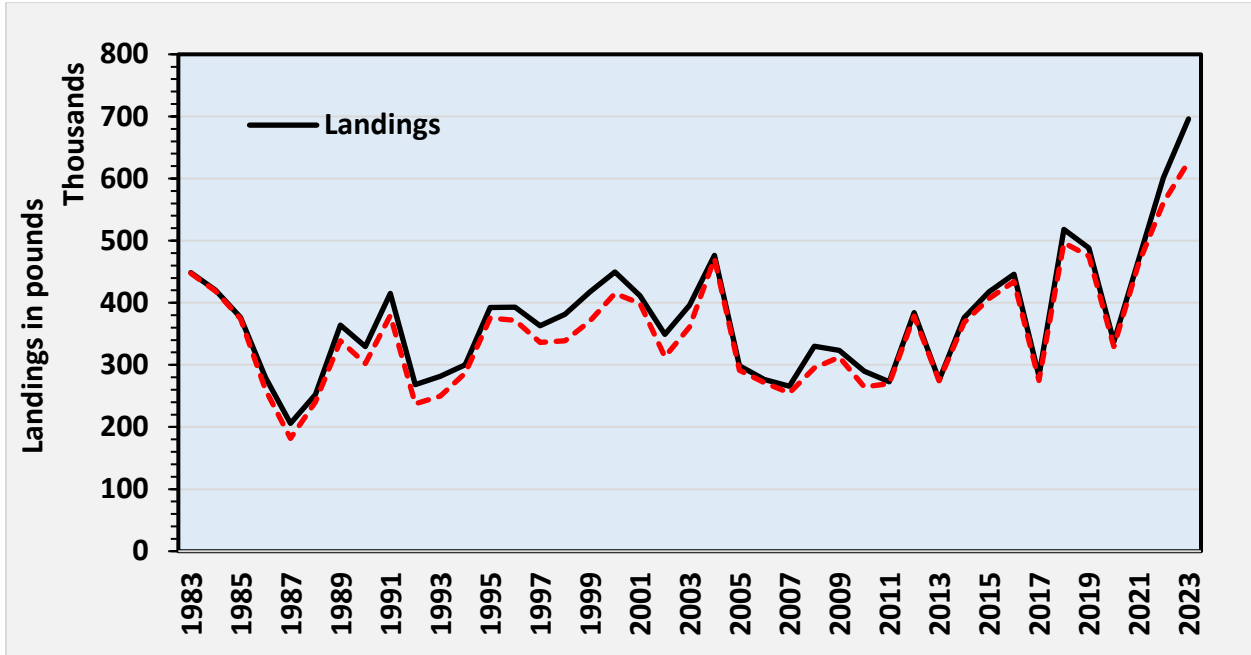


Figure 3.2.1 Commercial landings (pounds) of Caribbean Spiny Lobster of Puerto Rico with and without the outliers removed.



Figure 3.2.2 Map of the Municipalities of Puerto Rico.

4. Recreational Fishery Statistics

There are currently no data available on recreational landings in Puerto Rico.

5. Measures of Population Abundance

5.1 Overview

The panel was presented with a summary of the fishery-independent research conducted by SEAMAP-C during 2021-2023 (RD-12). Concerns were raised about using the data for an index of relative abundance, principally due to short time series and unequal sample sizes among years. The panel recommended that the data not be considered for use as an index of relative abundance in the PR assessment model, but noted that the CL composition data from all three years were substantive and warrant consideration for model-fitting.

Concerning fishery-dependent information, rising landings and decreasing or flat effort trends in the self-reported commercial logbook data demonstrated potential signs of hyperstability in catch-per-unit-effort. Members of the panel noted that the number of trips is likely not the best measure of effort for trap fisheries, for which effort is best measured in number of traps, for trips reporting that gear. The panel discussed possible alternative explanations for the patterns in landings and effort, including years of potentially high recruitment. The panel discussed the feasibility of standardizing a fishery-dependent index of relative abundance using the landings divided by the number of traps. However, the panel agreed that although there may be consistent trap effort reporting in logbooks, there is no such means for dive fisheries or nets, and the mechanism(s) that would explain the trend are not likely to be discernable, even though standardization.

Decision:

- No data were recommended for use in constructing an index of abundance for spiny lobsters in Puerto Rico.

6. Research Recommendations

- When developing new research projects, consider how those projects can be designed to include data collection and/or analyses that would inform ecosystem models and analyses. The original objectives of the project should not be compromised, however.

6.1 Life History Research Recommendation

- Life history studies focused on the US Caribbean – generate region-specific parameters for growth, fecundity, natural mortality.
- Look for ongoing growth/aging work via SEAMAP-C and DNER who is involved in doing histology for reproductive analyses.
- Merge selectivity studies, life history data collection, and fishery-independent survey frameworks to determine how to get best data for stock assessment.

6.2 Commercial Fishery Statistics

6.2.1 Length Composition Research Recommendations

- Compare SEAMAP-C, HJR Reefscaping, and MER Consultants CL composition to TIP size composition.

6.1.1 Commercial Landings Research Recommendations

- Track number of fishers/year in relation to annual landings- how does it vary?
- Support connectivity studies – consider spiny lobster as one stock vs. by island (metapopulation).
- Investigate weak/lack of correlation between TIP and landings data
- Demand analysis: look at price per pound (survey), market preferences, trends and correlation with landings, and for all islands.
- Investigate species associations with spiny lobster.
- Investigate recruitment connectivity between island platforms; e.g., STX seeding PR and other “hypotheses”.
- Increase funding for port samplers to improve TIP data collection in PR.
- Increase IT support for automated expansion factors calculation for the landings.

6.2.3 Discards and Discard Mortality Research Recommendations

- Discard information in the catch reports does not allow data on length or sex in current reporting schema.

6.3 Indices Research Recommendations

- There were no recommendations from the panel regarding use of fishery-independent data in the Puerto Rico assessment model. However, the panel recommended that analysts not explore standardization of fishery-dependent data for use as an index of relative abundance.

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Appendix – Fishing Landing Center Naming Conventions

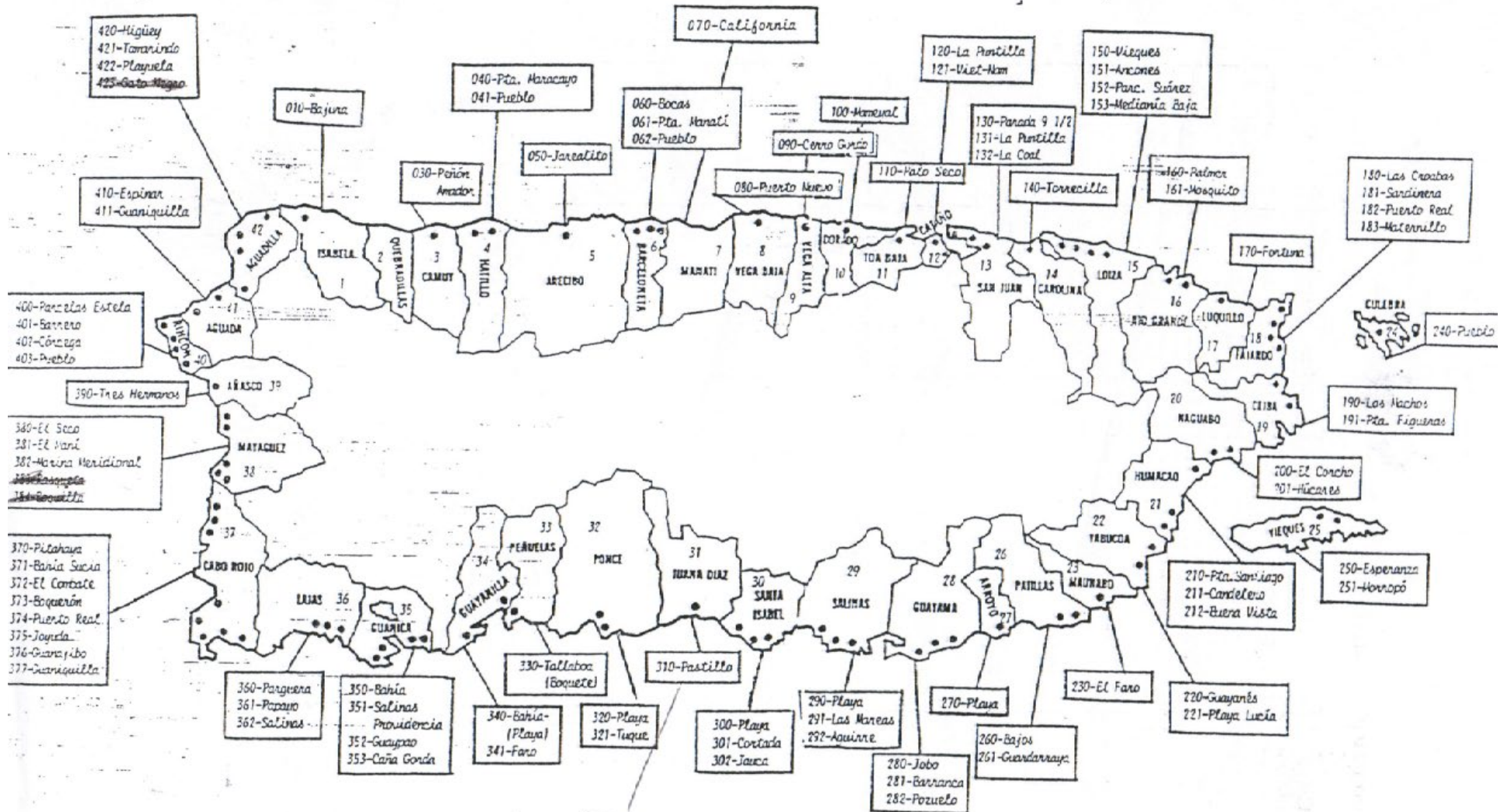
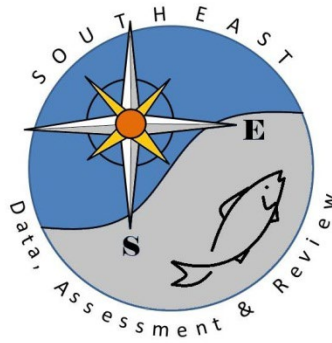


Figure Appendix 1. Map of Fishing Landing Centers in the Municipalities of Puerto Rico.



SEDAR

Southeast Data, Assessment, and Review

SEDAR 91

**US Caribbean Spiny Lobster –
Puerto Rico**

SECTION III: Assessment Process Report

August 2025

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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1. EXECUTIVE SUMMARY	

The SEDAR 91 Puerto Rico spiny lobster (*Panulirus argus*) stock assessment workshop consisted of four webinars between January 2025 and April 2025. The data available for the assessment included:

- An annual species-specific catch time series from commercial logbooks
- Fishery-dependent length compositions from commercial port sampling
- Fishery-independent length compositions obtained during 2021-2023 from the Puerto Rico SEAMAP-C dive survey program, and obtained during 2021-2022 from the HJR Reefscaping lobster trap survey
- Life history information carried over from the SEDAR 57 and SEDAR 57 update assessments

The assessment used Stock Synthesis, a statistical catch-at-age model (Methot et al., 2020). Stock Synthesis V3.30.12 models were fit to annual catch time series and annual length composition information for two fleets: dive and trap/pot fisheries and two sexes: females and males. Model development included stepwise fitting to catch and length composition; i.e., catch and then catch and length models were built, to ensure an analytical understanding of data impacts on model results. Model development included four models comprising the initial stages of development and the establishment of a single base model, and seven sensitivity analyses (Table 8.1; 12 models total). The selectivity analyses included: 1) each fleet selectivity was assigned a logistic (“flat-topped”) pattern, which was fixed or 2) estimable; 3) the Beverton-Holt stock-recruitment steepness parameter was fixed at 0.8; 4) the initial equilibrium catch for each fleet was set using the lowest and 5) the highest catch multiplier identified from the likelihood profile; 6) the coefficient of variation for the initial equilibrium catch was set to 0.3; and 7) growth and length-weight parameters for male and female lobster were fixed to male parameter values to approximate a single, combined sex model.

Model diagnostics assessed convergence, fit, and consistency using gradients, residuals, likelihood profiles, hindcast cross-validation, and jitter analyses. Those diagnostics indicated that the models were stable and converged on a global solution. Likelihood profiles suggested initial equilibrium catches for each fleet that were higher than the geometric mean calculated over landings values during 1985-1987. The minimum catch-multiplier value identified from the likelihood profiles was used in the base model. Model diagnostics are visually reported for the base model only for conciseness.

Sensitivity analyses for selectivity determined that fleet selectivity is dome-shaped for both dive and trap/pot fisheries. Initializing exponential logistic selectivity models with flat-topped selectivity patterns and allowing the model to estimate selectivity parameters resulted in the same dome-shaped selectivity patterns estimated when selectivity models were initialized as dome-shaped. This suggests that the length composition information can inform fleet selectivity parameter estimation. The sensitivity analysis of steepness indicated that the steepness parameter affects the magnitude of estimated biomass, but the parameter itself is not likely to be well-estimated given the data limitations. The sensitivity analysis in which size dimorphism was eliminated suggested that the stock is unexploited with extreme uncertainty bounds; this demonstrates the need for quantifying size dimorphism in Puerto Rico spiny lobster population dynamics. The sensitivity analysis of length-weight relationship parameters indicated that the Puerto Rico-specific parameters do not produce radically different population dynamics than those estimated for the US Caribbean region. Sensitivity analyses of initial equilibrium catch assumptions demonstrated the models' general sensitivity to initialization and the effects on stock status in the terminal year.

1.1 Background

US Caribbean spiny lobster (*Panulirus argus*) is a marine invertebrate that inhabits pelagic, nearshore vegetation, and coral reef habitats throughout its life history. Spiny lobsters inhabit the southeast US coast, Gulf of America, and greater Caribbean region. The Puerto Rico fishery targets adult spiny lobster on reef habitats.

2 INTRODUCTION

2.1 Workshop Time and Place

The SEDAR 91 Assessment Workshop was held via webinars from January to April 2025

2.2 Terms of Reference

Assessment Process Terms of Reference

1. Develop and apply assessment tools that are compatible with available data and consistent with standard practices. Document input data, model assumptions and configuration, and equations for each approach considered.
2. Characterize uncertainty in the assessment and estimated values.
 - a. Consider uncertainty in input data, modeling approach, and model configuration.
 - b. Provide appropriate measures of model performance, reliability, and ‘goodness of fit’.
 - c. Provide measures of uncertainty for estimated parameters and derived quantities such as biological reference points and stock status if feasible.
3. To the extent possible given data limitations, provide management benchmarks and status determination criteria, including:
 - a. Maximum Fishing Mortality Threshold (MFMT) = F_{MSY} or proxy
 - b. MSY proxy = yield at MFMT
 - c. Minimum Stock Size Threshold (MSST) = SSB_{MSY} or proxy
 - d. If alternative status determination criteria are recommended, provide a description of their use and a justification.
4. To the extent possible, develop projections to support estimates of maximum sustainable yield (MSY, the overfishing limit (OFL) and acceptable biological catch (ABC) as described below. If projections are not possible, and alternative management procedures are recommended, provide a description of their use and a justification.
 - a. Unless otherwise recommended, use the geometric mean of the three previous years’ fishing mortality to determine $F_{Current}$
 - b. Project F_{MSY} or proxy
 - c. If the stock is overfished:
 - i. Project F_0
 - ii. Project $F_{Rebuild}$
5. Provide recommendations for future research and data collection.
6. Provide an Assessment Workshop Report to address these Terms of reference and fully document the input data and results.

2.3 List of Participants

Assessment Panel

Matt Damiano (Lead Analyst).....	NMFS/SEFSC
Kevin McCarthy	NMFS/SEFSC
Erik Williams	NMFS/SEFSC
Jason Cope.....	NMFS/NWFSC

Appointed Observers

Nelson Crespo.....	CFMC Industry Rep
Julian Magras	CFMC Industry Rep

Gerson Martinez.....CFMC Industry Rep

Observers

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 Juan Agar.....NMFS/SEFSC
 Mandy Karnauskas.....NMFS/SEFSC
 Maria Lopez-MercerNMFS/SEFSC
 Stephanie Martinez.....NMFS/SEFSC
 Sarah Stephenson.....NMFS/SEFSC
 Katherine Godwin.....UM-CIMAS
 Rachel BantonUM-CIMAS
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 Hannah JacobsUM
 Manuel Coffill-Rivera.....University of South AL
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 Aida RosarioPR DNER
 Daniel Matos-CaraballoPR DNER
 Wilson Santiago Soler.....PR Fisheries Liaison
 Cristina Olan.....CFMC Staff

Staff

Emily Ott.....SEDAR
 Julie A. Neer.....SEDAR
 Graciela Garcia-Moliner.....CFMC Staff

2.4 List of Assessment Process Working Papers and Reference Documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Assessment Process			
SEDAR91-AP-01	Summary of Management Actions for Caribbean Spiny Lobster 1985-2023	Gaitlyn Malone	31 January 2025
Reference Documents			
SEDAR91-RD14	Catch curve stock-reduction analysis: an alternative solution to	James Thorson, Jason Cope	

	the catch equations	
SEDAR91-RD15	Accounting for variable recruitment and fishing mortality in length-based stock assessments for data-limited fisheries	Merill Rudd, James Thorson
SEDAR91-RD16	A 50-Year Reconstruction of Fisheries Catch in Puerto Rico	Richard Appeldoorn, Isle Sanders, Leonie Farber
SEDAR91-RD17	Final stock assessment and fishery evaluation (SAFE) report for the workshop on spiny lobster resources in the U.S. Caribbean San Juan, Puerto Rico, September 11-13, 1990	James Bohnsack, Stephen Meyeres, Richard Appeldoorn, Jim Beets, Daniel Matos, To
SEDAR91-RD18	Reflections of the way life used to be: Anthropology, History and the Decline of the Fish Stocks in Puerto Rico	Manuel Valdés-Pizzini

2.5 Stock Structure and Management Unit

Puerto Rico spiny lobster is managed under the Puerto Rico Fishery Management Plan (Crabtree, 2019). In 2023, the Caribbean Fisheries Management Council transitioned from species-based to island-based fisheries management (Figure 9.1). The management measures in the new island-based fishery management plans became effective on October 13, 2022.

The Puerto Rico spiny lobster stock is managed as an independent population. Catch limits for Puerto Rico spiny lobster are based on a tiered acceptable biological catch (ABC) control rule; it is currently managed under Tier 3: acceptable assessment available, using the models developed during SEDAR 57 (2019) and SEDAR 57 update (2022) processes. The most recent annual catch limit (ACL) is 357,629 lbs., whole weight.

A SEDAR 91 Assessment Process working paper summarizes federal management actions for spiny lobster in Puerto Rico (Malone, 2025). On January 1, 1985, a 3.5-inch federal size limit was instituted as part of the original fishery management plan. The size limit applies to the U.S. Exclusive Economic Zone (EEZ) surrounding Puerto Rico, which is defined as the federal waters ranging from 9 to 200 nautical miles (nm) (16.7 – 370 kilometers [km]) from the nearest coastline point of Puerto Rico (Figure 9.1).

3 DATA INPUT AND MODEL CONFIGURATIONS

3.1 Data-Informed Modeling Decisions

The data available for use in the current assessment are documented in the SEDAR 91 US Caribbean spiny lobster Puerto Rico Data Workshop Report (SEDAR, 2025). Provided here is a summary of those data with a focus on the associated model configurations explored using SS3. Throughout this report, bolded text is used to highlight and summarize the model settings and configurations relevant to the various phases of model development.

Additional details for each data input are available in their respective references:

1. **Landings** from self-reported commercial fisher logbooks (Orhun et al., 2024)
2. **Length compositions** from shore-based port sampling (Godwin and Rios., 2024)
3. **Length compositions** from the SEAMAP-C dive survey conducted in southwest Puerto Rico waters (Cruz Motta 2024)
4. **Length compositions** from HJR Reefscaping lobster trap survey conducted throughout Puerto Rico waters (Scharer et al. 2023)

Based on the available data, the assessment was configured with one area, one season, two sexes, two commercial fleets, and two survey fleets.

3.2. Commercial Fleet Data

3.2.1 Catch and Initial Equilibrium Catch Assumptions

Commercial fishery landings in Puerto Rico (PR) were obtained from self-reported fisher logbook data (Caribbean Commercial Logbook, CCL) (Orhun et al. 2024). Commercial fishery landings data for Caribbean spiny lobster in PR were available for the years 1983-2023 (Figures 9.2 and 9.3).

Potential outliers were discussed during the Data Workshop and the decision was made to remove them prior to building the stock assessment models. See the PR Data Workshop Report for a description of the outlier analysis (SEDAR, 2025).

During the Data Workshop process, concerns were expressed over whether landings in PR made prior to 1985 consisted solely of lobsters caught within PR's EEZ. Data Workshop panelists had recommended that the lead analyst be granted the flexibility to explore the start year of the model, with 1985 as the recommended start year. Due to known general sensitivity of statistical catch-at-age models to initial equilibrium catch assumptions, members of the Assessment Panel recommended that the analyst attempt a catch reconstruction to avoid the need for said assumptions.

A historical catch reconstruction was attempted based on the percentage of total PR catches during 1950-1984 that were shellfish and the percentage of shellfish that were spiny lobster derived by Appeldoorn et al. (2015), and the percentage of landings by pot/trap and

dive gear prior to 1985 that were identified by Bohnsack et al. (1990). Ultimately, the reconstruction was not possible due to the confounding of catches from other Caribbean island waters with those from PR's EEZ prior to 1985 (Valdés-Pizzini et al. 2008).

Therefore, although the years of the available species-specific self-reported commercial fisher logbook landings and effort data included 1983-2023, **the start and end years of the model were 1985 and 2023, respectively.**

In the SEDAR 91 SS3 models, **the catch was input as biomass (in metric tons) and was treated as if it occurred over an entire fishing season; i.e., each fishing year (Figure 9.2). Catches are assumed to be approximately known with a standard error of 0.01 for each fleet.**

Fishing for spiny lobster by PR has occurred since at least the 1950s (Valdes-Pizzini 2008, Appeldoorn et al. 2015). In SEDAR 57, the initial equilibrium catch prior to 1983 was assumed to be 200 metric tons (mt); the pot/trap fishery was still in the early stages of development during the early 1980s, and the 200 mt was associated with the dive fleet, which was the only fleet for which an initial fishing mortality (F) was estimated (SEDAR 2019). Given the small magnitude of pot/trap landings at the time, this was a reasonable assumption. The *init* model configuration maintains this assumption (Table 8.1), but it became clear that this was no longer appropriate because the magnitude of pot/trap landings had increased substantially by 1985. In order to address this, the initial equilibrium catch was set to the geometric mean of each fleet's respective catches during 1985-1987 and an initial F was estimated for each fleet (see *2Finit* model configuration in Table 8.1). Likelihood profiling of equilibrium catch (Figure 9.25) suggested that the global solution was somewhat larger than the combined geometric means. Therefore, **the initial equilibrium catch was calculated by multiplying the geometric mean catches during 1985-1987 for each fleet by a catch multiplier such that their combination was equal to the global solution, and a separate initial F was estimated for the pot/trap and dive fleets, respectively.**

Three sensitivities were conducted to explore the effect of alternative equilibrium catch assumptions. The first sensitivity set the initial equilibrium catch to the lowest value in the likelihood profile (see section 4.10; the second sensitivity set the initial equilibrium catch to the highest value in the likelihood profile; and the third sensitivity set the coefficient of variation for initial equilibrium catch to 0.3.

3.2.2 Size Composition, Quantile Analyses, and Gear Selectivity

Gear-specific annual length frequencies for the commercial fleet came from the commercial shore-based port-sampling Trip Interview Program (Godwin and Rios, 2024). The Puerto Rico Department of Natural Environmental Resources (PR DRNA), as part of the Trip Interview Program (TIP), collects length and weight data from fish landed by commercial fishing vessels, along with information about fishing areas and gears. Data collection began in the 1980s and are available for PR spiny lobster during 1981-2023 (Figure 9.3). **The relative model weighting of each commercial fleet's length compositions was based on the number of trips sampled.**

From 1981 - 2023, the TIP data contain 69,065 length observations across 7,894 unique port sampling interviews.

The TIP length compositions of the commercial fleets were assumed to be representative of the total catch. Although non-commercial fishing is reported to occur, it is assumed to be constant over time such the former assumption can hold.

An analysis of the length composition median quantiles was conducted for each fleet by sex to determine the relative estimability of fishing mortality and recruitment deviations (Figures 9.4:9.7). Median 10th, 25th, 50th, 75th, and 90th quantiles were calculated for female and male lobster each year for each commercial fleet. Median quantiles in the dive fishery over time are center consistently around the average size of spiny lobster with little to no trend for females and males (Figures 9.4, 9.5). Additionally, the shrinking of quantiles around 1999 follows the increased enforcement of the minimum size limit (Figures 9.4, 9.5). There is more of a pattern in the quantiles of the pot/trap TIP data for both females (Figure 9.6) and males (Figure 9.7). Similar to the dive fleet, the quantiles contract around the year 2000 due to increased enforcement of the minimum size limit (Figures 9.6, 9.7). The spike in female quantiles in 2008 (Figure 9.6) reflects a data point that was removed during SEDAR 57 (2019) and is not included in model-fitting. The contraction of quantiles in 2020 (Figures 9.6 and 9.7) was likely due to low TIP sampling effort resulting from the COVID-19 pandemic. Despite some limited contrast in the data, annual recruitment deviations are unlikely to be estimable. Median quantile analyses for both fleets suggest that fishing has not had an effect on the overall size structure of the population.

An exponential logistic function (Equation 1, Methot et al. 2020) was used to model the relative vulnerability of capture by length for the dive and pot/trap fleets (Figure 9.8):

$$\text{Selectivity} = \frac{e^{2nd\ limb * 1st\ limb * (asymptote - length)}}{1 - 2nd\ limb * (1 - e^{1st\ limb * (asymptote - length)})} \quad (1).$$

The three-parameter exponential logistic function can be used to model both dome and logistic and flat-topped selectivity patterns. Additionally, a fixed time-varying knife-edged retention function was included to model the minimum-size limit and retention of male spiny lobsters in both the dive and pot/trap fisheries this model assumes that discarding of under-sized lobster occurs following the heavy enforcement of the size limit (1999-2000), but that no mortality from discarding occurs (Figure 9.9, 9.10).

SEAMAP-C length composition data were obtained by divers targeting all sizes of lobster off the Southwest coast of PR during 2021-2023 (Cruz Motta et al. 2024). A total of 558 unique length observations were recorded. Sampling occurred in all months during 2022 and some months during late 2021 and early 2023. **Based on the recommendations from the Assessment Panel, all samples were aggregated into 2022 for model-fitting.**

Due to the lack of selectivity information for SEAMAP-C, **an exponential logistic function was used to model the relative vulnerability of capture by length for the SEAMAP-C survey with selectivity parameters estimated within the model. Selectivity parameters were initialized at the same values as the dive fleet.**

HJR Reefscaping length composition data were obtained by licensed fishers participating in a pot/trap survey targeting lobsters 50-89 millimeters carapace length, and conducted as part of a cooperative research program with the Southeast Fisheries Science Center during 2021-2022 (Scharer et al. 2023). A total of 808 samples were collected from the Southwest, East and Northeast waters of PR, and the majority of sampling occurred during January – September, 2022. **Based on the recommendations of the Assessment Panel, all samples were aggregated into 2022 for model-fitting.**

Due to the lack of selectivity information for the HJR survey, **an exponential logistic function was used to model the relative vulnerability of capture by length for the HJR Reefscaping survey with selectivity parameters estimated within the model. Selectivity parameters were initialized at the same values as the pot/trap fleet.**

3.3 Life History Data

The life history data used in the assessment included an island-specific length-weight conversion estimated from 22,980 length-weight observations in the TIP data. No other empirical life history

information was used in the model. See the PR Data Workshop Report for additional detail. Based on the available information, **the spiny lobster population was modeled from age 0 through age 15, which was treated as a plus group, and from 5 to 250-millimeters (mm) carapace length. Note that only lobsters 51 mm or larger were observed in the TIP data.** Note that SS3 assumes that inputs are in centimeters. However, if length data and life history relationships are input and parameterized using millimeters, SS3 will produce consistent results. This was the approach in both SEDAR 57 and the 2022 update (SEDAR 2019, 2022). Also note that length-related SS3 outputs will automatically generate figures with centimeter units, but for the purposes of this assessment, it should be interpreted in millimeters.

3.3.1 Growth

The SS3 growth formulation requires five parameters:

1. Length at the youngest age
2. Length at the maximum age
3. Von Bertalanffy growth parameter (K)
4. Coefficient of variation at the youngest age
5. Coefficient of variation at the maximum age

Based on feedback from the Data Workshop, growth model parameters were carried over from SEDAR 57 with no recommended changes. Von Bertalanffy growth function parameters were sex-specific and assumed fixed. Length at the youngest age was fixed at 5 mm for both males and females, and the length at the maximum age was fixed at 155 and 184 mm, respectively. K was fixed at 0.22 and 0.24 for males and females, respectively. The coefficient of variation at the youngest age was set to 0.1, and oldest age at 0.043 for both males and females. These parameters remain unchanged from SEDAR 57 (2019). Note that the length at maximum age for each sex is treated as an average by the model; larger lobsters have been observed in the data and can be estimated by the model.

The Assessment Panel expressed some concerns about the need for sex-specific growth parameters in the model. **Therefore, a sensitivity was conducted in which all five growth parameters for female and male lobster were fixed at the male parameter values, and length-weight parameters for each sex were fixed to male parameter values:** this forces the model to assume that there is no size dimorphism in the population dynamics, and that the male growth pattern represents all growth processes.

3.3.2 Length-Weight Conversion

The relationship between weight in kilograms and carapace length in millimeters was estimated using a linear regression on the log-transformed exponential equation fit to the TIP data. The original length-weight relationship for males was $W = 6.8 \times 10^{-5} * L^{2.54}$, and was $W = 7.6 \times 10^{-5}$ millimeters. $* L^{2.52}$ for females with weight (W) in kilograms and length (L) in millimeters.

During SEDAR 91 model development, it was discovered that the PR models in SEDAR 57 and the update assessment had been parameterized with the length-weight relationship parameters estimated for St. Croix. Additionally, because the PR length-weight relationship had been calculated from TIP data that include samples taken prior to 1985 (SEDAR 2025), new length-weight relationship parameters were estimated for PR. The new length-weight relationship parameters were estimated using the log-scale linear regression model described in the PR Data Workshop Report (SEDAR 2025), but applied to TIP data during 1985-2024 in order to update the relationship and exclude any lobster potentially caught outside of PR, i.e., lobster caught prior to 1985. **The new length-weight relationship for males was $W = 1.1 \times 10^{-5} * L^{2.44}$, and was $W = 9.4 \times 10^{-6}$ millimeters. $* L^{2.475}$ for females with weight (W) in kilograms and length (L) in millimeters.**

One sensitivity model was explored for the length-weight relationship. Length-weight parameters for the entire US Caribbean region were estimated using the same linear regression method (SEDAR 2025), but applied to data from PR during 1985-2024. The sensitivity analysis were applied these regional length-weight parameter estimates to determine if there are population-level differences when island-specific vs. regional estimates of length-weight parameters were applied. The regional length-weight relationship for males was $W = 1.1 \times 10^{-5} * L^{2.44}$, and was $W = 9.4 \times 10^{-6}$ millimeters. $* L^{2.475}$ for females with weight (W) in kilograms and length (L) in millimeters.

3.3.3 Maturity and Fecundity

Maturity was modeled as a logistic function and parameters were treated as fixed inputs to the model. Parameter estimates for maturity were estimated using TIP data prior to 1990 when harvest of egg bearing females was allowed (Die 2005). **The fecundity of spiny lobster is modeled as a power function** with parameter estimates from Cuba spiny lobster (FAO 2001):

$$E = 0.5911L^{4.5677}$$

where E is number of eggs and L is carapace length in mm. **Fecundity parameters were treated as fixed inputs to the model.**

3.3.4 Stock Recruitment

A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting recruitment of age-0 lobster.

The stock-recruit function requires three parameters:

- Steepness (h) characterizes the initial slope of the ascending limb (i.e., the fraction of recruits produced at 20% of the unfished spawning biomass).
- The virgin recruitment (R_0 ; estimated in log space) represents the asymptote or unfished recruitment levels.
- The variance term (sigma R) is the standard deviation of the log of recruitment and describes the amount of year-to-year variation in recruitment.

Only the virgin recruitment (R_0) was estimated. **Sigma R and steepness were fixed at 0.7 and 0.99, respectively.** The 0.7 sigma R reflects slightly high variation in recruitment. A value of 0.6 is a moderate level of recruitment variability, with lower values indicating lower variability and more predictable year-to-year recruitment. The primary assumption for steepness was that this stock is not a closed population, so recruitment may not be strongly tied to the local spawning stock biomass. **Due to the low contrast in length composition data, annual deviations from the stock-recruit function were not estimated.** A sensitivity indicated that recruitment deviations cannot be estimated well and resulted in nearly identical estimates of the four model parameters. Steepness and R_0 were explored via likelihood profiling.

3.3.5 Maximum Age and Natural Mortality

Natural mortality was treated as a fixed model input set to 0.34: the same value used in SEDAR 57 (2019). This value is based on a point estimate calculated from a variant of Pauly's equation (Cruz et al. 1981). Past considerations of natural mortality are discussed in the Data Workshop Report Section 2.4 (SEDAR, 2025).

Empirical estimates of natural mortality (M) can be derived using life history information such as longevity, growth, and maturity. The Assessment Panel recommended that the Natural Mortality Tool (Cope & Hamel, 2022) be used to determine if 0.34 is still a reasonable value for natural mortality. Parameters for maximum age, the Von Bertalanffy

growth parameter (K), and asymptotic size (L_{∞}), for females and males that are used in the current assessment were treated as inputs to the Natural Mortality Tool to obtain values of M from various empirical estimators. Maximum age was assumed to be 16 to approximate the age 15 plus group, and a lognormal coefficient of variation of 0.2 was included for uncertainty. The empirical estimators can be broken into two groupings: those based on maximum age (“Then_nls,” “Then_lm,” “Hamel_Amax”) and those based on the von Bertalanffy growth function (“Then_VGBF,” “Hamel_k,” “Jensen_k1,” “Jensen_K2”; see Cope and Hamel, 2022 for additional details on estimators). The average estimated natural mortality across estimators was very close to 0.34 for both sexes (Figures 9.11, 9.12), and therefore no changes to the fixed parameter input were considered.

3.4 Summary of Data-Informed Modeling Configurations

Based on the available data, the assessment was configured with one area, one season, two sexes, two commercial fleets, and two survey fleets. SS3 models were configured using annual commercial catch time series and size compositions by fleet.

3.4.1 Commercial Fleets

- The catch was input as biomass (in metric tons) and was treated as if it occurred over the calendar year.
- The start and end years of the model were 1985 and 2023, respectively.
- The input standard error for the landings was set to 0.01.
- The equilibrium initial catch for each fleet was based on the geometric mean of landings during 1985-1987 multiplied by the catch multiplier associated with the global minimum solution for initial equilibrium catch from the likelihood profile (Figure 9.25).
- The input coefficient of variation for initial equilibrium catch was 0.1 for both dive and pot/trap catches.
- Initial F was estimated individually for dive and pot/trap fleets.
- The relative model weighting of the commercial fleet length compositions was based on the number of trips sampled.
- The length compositions of the commercial fleets were assumed to be representative of the total catch.
- An exponential logistic function was used to model the relative vulnerability of capture by length for the dive fleet.
- An exponential logistic function was used to model the relative vulnerability of capture by length for the pot/trap fleet.
- The assessment assumed a time-varying retention function for the pot/trap fishery, but assumed

no mortality from discards.

- The assessment assumed a time-varying retention function for the dive fishery, but assumed no mortality from discards.
- A sensitivity was conducted in which initial equilibrium catch was set to the lowest value in the likelihood profile.
- As sensitivity was conducted in which initial equilibrium catch was set to the highest value in the likelihood profile.
- A sensitivity was conducted in which the coefficient of variation for initial equilibrium catch was set to 0.3.

3.4.2 Survey Fleets

- An exponential logistic function was used to model the relative vulnerability of capture by length for the SEAMAP-C dive survey; parameters were initialized using the dive fleet selectivity parameters and allowed to estimate.
- An exponential logistic function was used to model the relative vulnerability of capture by length for the HJR Reefscaping survey; parameters were initialized using the pot/trap fleet selectivity parameters and allowed to estimate.
- A sensitivity was conducted in which each fleet's exponential logistic function parameters were initialized with a logistic selectivity pattern and the asymptote and 2nd limb parameters fixed (part of the same sensitivity for commercial fleets).
- A sensitivity was conducted in which each fleet's exponential logistic functions were initialized with a logistic selectivity pattern and allowed to estimate all three parameters (part of the same sensitivity for commercial fleets).

3.4.3 Life History

- The spiny lobster population was modeled from age 0 through age 15, which was treated as a plus group, and from 5 to 250-millimeters carapace length, in 5-millimeter bins.
- Growth parameters for females and males were treated as fixed model inputs and carried over from SEDAR 57.
- Coefficients of variation for younger and older ages were initially set to 0.1 and 0.043 for both sexes.
- The length-weight relationship for male lobster was $W = 1.1 \times 10^{-5} L^{2.44}$, and $W = 9.4 \times 10^{-6} L^{2.475}$ for female lobster, with weight in kilograms and length in millimeters.

- A natural mortality value of 0.34 was used in the initial model runs.
- Maturity was modeled as a logistic function and fecundity was modeled as a power function with parameters treated as fixed model inputs.
- A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting recruitment of age-0 lobster.
- Sigma R and steepness were fixed at 0.7 and 0.99, respectively.
- In model configurations, annual deviations from the stock-recruit function were not estimated.
- A sensitivity was conducted in which steepness was fixed at 0.8.
- A sensitivity was conducted in which the von Bertalanffy growth parameters and length-weight relationship parameters are the same for males and females; the model assumes a male growth pattern.
- A sensitivity was conducted in which regional length-weight parameter estimates were applied instead of the PR island-specific parameters.

4. STOCK ASSESSMENT MODEL RESULTS

4.1 Overview

This report summarizes and discussed the results of five models that were developed sequentially: *init*, *2Finit*, *seamapc*, *hjr*, culminating in the base model: *new_eq* (Table 8.1). The *init* model configuration was configured nearly identically to the SEDAR 57 updated assessment (2022), but fit to commercial landings and TIP data during 1985 – 2023; the *2Finit* model addressed the need for initial equilibrium catch assumptions for the pot/trap fleet, and therefore required estimation of fleet-specific initial F; the *seamapc* configuration added the aggregated SEAMAP-C length composition data for the model to fit to during 2022; the *hjr* configuration added the aggregated HJR Reefscaping length composition data for the model to fit to during 2022; and after exploring a likelihood profile of total initial equilibrium catch (Figure 9.25) the *new_eq* model configuration assumed equilibrium catches for each fleet that were consistent with the global minimum likelihood profile, and was recommended by the Assessment Panel as the model framework from which to conduct future analyses (Table 8.1). Results are presented for the base model, *new_eq*. The stock assessment analyst investigated alternative stock assessment modeling frameworks designed specifically for marine invertebrates, however, the lack of an index of relative abundance for spiny lobster precluded the application of alternative frameworks to SS3. Therefore, the SS3 models remain the best benchmark stock assessment approach for US Caribbean spiny lobster.

Additionally, this report summarizes eight sensitivity analyses. Two sensitivities related to all fleet selectivities were conducted: the *selex1* model refers to the sensitivity in which the exponential logistic function is initialized with a logistic selectivity pattern and the asymptote and 2nd limb parameters are fixed, and *selex2* refers to the model in which the logistic selectivity pattern is initialized but all three parameters are estimated. Three sensitivities related to life history were conducted: the *steep* model, which explored the effect of the steepness parameter value being fixed at 0.8, and the *combsex* model, which explored the effects of treating growth patterns for both sexes set to that of male lobster. The *lw* model is a sensitivity in which US Caribbean-wide parameter estimates for each sex were applied instead of the PR-specific length-weight relationship parameters. Three sensitivities related to initial equilibrium catch assumptions were conducted: *eq_hi* and *eq_lo*, which collectively explored the effect of high and low magnitude of initial equilibrium catch, respectively, and *eq_cv_hi*, which explored the effect of a larger cv (0.3) associated with the initial equilibrium catches by fleet in *new_eq*.

4.2 Model Diagnostics

Model diagnostics aimed to follow the conceptual process described by Carvalho et al. (2021). Their approach includes evaluating goodness of fit, information sources and structure, prediction skill, convergence, and model plausibility. To that effect, model diagnostics included likelihood profiles, retrospective, and jitter analyses.

4.3 Convergence

Three approaches were used to check for model convergence. They were investigating for the presence of (1) bounded parameters, (2) high final gradients, and (3) a positive definite hessian. As described by Carvalho et al. (2021) checking for bounded parameters can indicate discrepancies with data or model structure. Additionally, small final gradients and a positive definite hessian can indicate that the objective function achieved good convergence.

The models presented in this report all had a positive definite Hessian, indicating that each reached a local minimum and a locally optimal fit. None of the models had parameters that were bounded, suggesting the optimization was not constrained by parameter limits. Finally, the parameter gradients in all models were small and well below 0.001 (Table 8.2).

4.4 Correlation Analysis

High correlation among parameters can lead to flat response surfaces and poor model stability. By performing a correlation analysis, modeling assumptions that lead to inadequate configurations can be identified. Because of the highly parameterized nature of stock assessment models, some parameters are expected to be correlated (e.g., stock recruit parameters). However, many strongly correlated parameters suggest reconsidering modeling assumptions and parameterization.

No high correlations (correlation coefficients greater than 0.95 or less than -0.95) were observed. Correlations primarily occurred between selectivity parameters (Table 8.3). These correlations were expected.

4.5 Evaluating Variance

To check for parameters with high variance, parameter estimates are reported with their resulting standard deviations (stdev). Table 8.2 presents the *eq_new* model-estimated values and standard deviations for the main active parameters. Parameters estimates ranged from precise (stdev ≤ 0.1) to relatively precise ($0.1 < \text{stdev} < 0.3$), to imprecise (stdev > 0.3) (Table 8.2). Most parameters, e.g., R_0 , initial F for dive and pot/trap fleets, and fleet/survey selectivity parameters were estimated with relative precision (Table 8.2) within their respective probability density functions (Figure 9.13). The most imprecise parameter estimates were selectivity parameters associated with the SEAMAP-C and HJR Reefscaping survey fleets; this was not unexpected given that there is only one year of data to which the model is fitted in order to estimate selectivity. Model outputs of interest to management, e.g., relative biomass (biomass relative to the target level), spawning biomass, F, and recruitment are shown for the *new_eq* model in Figure 9.14.

4.6 Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether the search algorithm has found a global, as opposed to local, solution. The premise is that all starting values are randomly altered (or 'jittered') by an input constant value, and the model is rerun from the new starting values. If the resulting population trajectories across many runs converge to the same solution, this provides support that a global minimum has been obtained. This process is not fault-proof; no guarantee can ever be made that the 'true' solution has been found or that the model does not contain misspecification. However, if the jitter analysis results are consistent, it provides additional support that the model is performing well and has come to a stable solution. Furthermore, jitter analyses, when jittered at appropriately high values, can provide insight into whether a

more optimal solution space exists, i.e., a lower total negative log-likelihood. For this assessment, a jitter value of 0.5 was applied to the starting values, and 40 runs were completed. The jitter value defines a uniform distribution in cumulative normal space to generate new initial parameter values (Methot et al., 2020).

Consistent with earlier results indicating that the models reached local minima (positive definite Hessian), the jitter analysis also performed well, indicating that nearly all models converged to the same solution (Figure 9.15). Some jitter runs produced higher likelihoods, but importantly, no jitter runs produced a lower likelihood than the best fit already identified for each model.

4.7 Residual Analysis

The primary approach to investigate model performance was a residual analysis of model fit to each data set. Any temporal trend in model residuals or disproportionately high residual values can indicate model misspecification and poor performance. Ideally, residuals are randomly distributed, conform to the assumed error structure for that data source, and are not of extreme magnitude. Any extremely positive or negative residual patterns indicate poor model performance and potential unaccounted-for process or observation error.

4.7.1 Catch

SS3 uses a hybrid implementation of Pope's approximation to internally tune the model such that fishing mortality need not be an estimated parameter, but an internally-tuned coefficient to produce values of fishing mortality associated with a perfect fit to catch data (Figure 9.14c) (Richard Methot, NOAA Fisheries Directorate, personal communication). Therefore, observed and predicted catches match more or less exactly.

4.7.2 Length compositions

Figure 9.16 shows the cumulative fit across all years between the observed and predicted length composition for the base model by sex, and fleet, and Figures 9.17 and 9.18 show the individual fits to length composition by year for the dive and pot/trap, respectively. **Note that SS3 assumes that length composition data are in centimeters (cm) and generate plots to this effect; all measurements are in mm.** Cumulative fits were reasonable with some overestimation of 100 mm females (Figure 9.17); this pattern was likely driven by poor model fits to data during years with low sample sizes (Figure 9.17, 9.18). Years in which sample sizes were sufficiently large resulted in close fits to the length composition data (Figure 9.17, 9.18).

4.8 Retrospective Analysis

A retrospective analysis is a helpful approach for investigating the consistency of terminal year model estimates (e.g., SSB) and is often considered a sensitivity exploration of impacts on key parameters from changes in data. The analysis sequentially removes a year of data and reruns the model. Suppose the resulting estimates of derived quantities such as SSB or recruitment differ significantly. In such a case, serial over- or underestimation of important quantities can indicate that the model has an unidentified process error and could require reassessing model assumptions. It is expected that removing data will lead to slight differences between the new terminal year estimates and the estimates for that year in the model with the complete time series of data. Estimates in years before the terminal year may have increasingly reliable information on cohort strength. Therefore, slight differences are usually expected between model runs as more years of size composition data are sequentially removed. Ideally, the difference in estimates will be slight and randomly distributed above and below the estimates from the model with complete data set time series. The results of a five-year retrospective analysis for SSB are plotted in Figure 9.19, which shows no evidence of a retrospective pattern.

4.9 Hindcast Cross-validation

Hindcast cross-validation uses SS3's forecast file to calculate the expected values of the observed data based on forward projections (Carvalho et al. 2021), which can be used to test the model's ability to predict mean values, e.g., length composition, by projecting a number of years backward from the terminal year. Model prediction ability is diagnosed with mean absolute square error (MASE) scores. Scores less than 1.0 indicate some predictive ability while values of 1.0 or greater indicate that the model performs equivalently with a random walk model, i.e., does not have predictive ability.

Hindcast cross-validation was applied to the length composition data for each commercial fleet. MASE scores indicate that the model can predict mean length composition for pot/trap fleet (Figure 9.20). Although the MASE score is greater than 1.0 for the diving fleet, i.e., not indicative of predictive ability greater than a random walk model, the hindcasted values for mean length still match those of observed mean length (Figure 9.20).

4.10 Likelihood Profiles

Profile likelihoods are used to assess the stability of parameter estimates by examining changes in the negative log-likelihood for each data source and evaluating the influence of

each source on the estimate. The analysis is performed by holding a given parameter at a constant value and rerunning the model. The model is run repeatedly over a range of reasonable parameter values. Ideally, the graph of change in likelihood values against parameter values will yield a well-defined minimum. When the profile plot shows conflicting signals or is flat across its range, the given parameter may be poorly estimated.

Typically, profiling is carried out for key parameters, particularly those defining the stock-recruit relationship (steepness, virgin recruitment, and sigma R). However, due to the extensive sensitivity analyses conducted during SEDAR 57 (2019), profiles were exclusively explored for unfished recruitment (R_0), steepness, initial F for the dive fleet, initial F for the pot/trap fleet, and initial equilibrium catch.

4.10.1 Unfished Recruitment (R_0)

Figure 9.21 shows the profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for PR spiny lobster (*new_eq* model only). The base model log-scale R_0 profile indicates a well-defined minimum occurring at the base model estimate of R_0 (Table 8.2). The scale of the profile, however, indicates that other values of R_0 may be nearly as probable.

4.10.2 Steepness

Figure 9.22 shows the profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for PR spiny lobster (*new_eq* model only). The base model profile indicates that the global solution for the steepness parameter is around 0.85, closely followed by 0.9, which was slightly less probable. Multiple values of steepness could be equally probable in describing PR spiny lobster population dynamics, but it is more likely that steepness is not estimable given the limitations of the data.

4.10.3 Initial Fishing Mortality (Dive)

Figure 9.23 shows the profile likelihood for the initial F for the PR spiny lobster dive fishery (*new_eq* model only). The dive initial F profile indicates that a global minimum solution was obtained for the parameter.

4.10.4 Initial Fishing Mortality (Pot/trap)

Figure 9.24 shows the profile likelihood for the initial F for the PR spiny lobster pot/trap fishery (*new_eq* model only). The pot/trap initial F profile indicates that a well-

defined global minimum solution was obtained for the parameter.

4.10.5 Initial Equilibrium Catch

Figure 9.25 shows the profile likelihood for the total initial equilibrium catch for PR spiny lobster (base model only). The likelihood profile indicates that the global minimum estimate of initial equilibrium catch occurs at approximately 160 mt. The catch multiplier associated with this value was applied to the geometric mean catches by fleet used in the four initial stage models to create the *new_eq* base model. Similar to the R_0 profile, the scale of the initial equilibrium catch profile is relatively low, and therefore the model will consider higher and lower values as nearly as probable. The effects of alternative initial equilibrium catch assumptions (magnitude and cv) are also illustrated in Figure 9.26.

4.11 Sensitivity Runs

Seven sensitivity analyses were conducted. Two sensitivity analyses were conducted to determine the estimability of selectivity for all fleets. *Selex1* explored initializing each fleet's exponential logistic function with parameters that generate a logistic selectivity pattern, and treats the asymptote and 2nd limb parameters as fixed inputs. *Selex2* explored initializing all fleets' exponential logistic functions with parameters that generate a logistic selectivity pattern, but allows the model to estimate all three parameters. Estimated selectivity patterns each of the SEDAR 91 models (*new_eq* (base), *selex1*, *selex2*) are provided in Figure 9.8. Assuming fixed logistic selectivity for all fleets results in dramatically reduced relative biomass (Figure 9.26) due to higher estimates of initial F and an associated lower estimate of R_0 (Table 8.5); this was expected because the logistic selectivity and retention functions overlap and tell the model that no lobsters are discarded and survive. Despite the relatively low resolution in the median quantiles of the length composition data, the exponential logistic function in *selex2* estimates nearly identical parameters as the base model, resulting in the same dome-shaped selectivity patterns (Figure 9.8).

Three sensitivity analyses related to life history were conducted. The *steep* model fixed the stock-recruitment steepness parameter to 0.8. This resulted in a slightly lower estimate of relative biomass over time (Figure 9.26). Assuming a steepness value of 0.8 still allows the model to generate a large number of recruits per spawner, but it is no longer one-to-one as it would be with a value of 0.99. The *combsex* model assumed that von Bertalanffy growth parameter inputs and length-weight relationship parameters were equal to male lobster values for both male and females to approximate a combined sex model; this was done to explore the effect of removing size dimorphism assumptions from the model. This resulted in an estimate of relative biomass that was essentially unexploited over time,

but extremely uncertain (Figure 9.26). The estimates of initial F were low and the estimate of R_0 was correspondingly high (Table 8.5). The results of this sensitivity analysis indicate the importance of including sex dimorphism in the model, particularly with respect to von Bertalanffy growth parameter inputs; to which the model is highly sensitive (SEDAR 2019). The length-weight relationships do not differ greatly between islands (see PR Data Workshop Report), and lw sensitivity produced nearly identical population dynamics to the `new_eq` model, albeit with marginally lower R_0 (Table 8.5).

Three sensitivity analyses related to initial equilibrium catch assumptions were conducted. The `eq_hi` model assumed that initial equilibrium catch was approximately 230 mt, and the `eq_lo` model assumed that initial equilibrium catch was approximately 70 mt, resulting in the model initializing at higher and lower levels of relative depletion (Figure 9.26); both models resulted in higher terminal estimates of relative biomass than the base model (Figure 9.14a), however, the former is likely driven by the high degree of compensation driven by the steepness parameter being set to 0.99, while the latter is likely due to small predicted impact of fishing mortality over time (Table 8.5). The `eq_cv_hi` model set the initial equilibrium catch coefficient of variation (cv) to 0.3, an increase from the base model's 0.1. This resulted in a much more uncertain initialization (Figure 9.26), but otherwise identical model results (Figure 9.14a).

5. DISCUSSION

This assessment presents a total of 13 model configurations, using an integrated framework and several model diagnostics in order to characterize the stock status of spiny lobster in PR. The results broadly indicate that overfishing is occurring, but the stock is not overfished (Figure 9.14a, Table 8.6). Estimated catch at the MSY proxy target did not differ radically among the five primary models (Table 8.7). Catches have increased in recent years (Figure 9.2), but PR Department of Natural and Environmental Resources have reported evidence of high abundance in PR's EEZ (Matos-Caraballo et al. 2024). The results of the quantile analysis suggest that fishing has not affected the size structure of the population (Figures 9.4-9.7), therefore it is unclear whether the level of exploitation occurring in PR waters is at a higher or lower level of population biomass. The results of the R_0 , steepness, and initial equilibrium catch likelihood profiles (Figures 9.21, 9.22, 9.25) suggest a broad range of possible parameter values that can describe PR spiny lobster population dynamics, and in some instances, change the scale of depletion over time (Figure 9.26). Taken together, the evidence presented in this report and related documents suggest that the PR spiny lobster fishery is sustainable (Table 8.6), but that the magnitude of exploitable biomass is highly uncertain.

The SEDAR 91 model for PR spiny lobster is an advancement of the same framework applied during SEDAR 57 and its update (2019, 2022). The assessment model was fit to two new fishery-independent sources of length composition data, included a more realistic start year for fishing occurring within PR's EEZ, and estimated an additional seven parameters: initial F for the pot/trap fishery, and three exponential logistic selectivity parameters for the SEAMAP-C and HJR Reefscaping survey fleets, respectively. Uncertainty in selectivity, life history, and initial equilibrium catch was quantified via model diagnostics and sensitivity analyses. Sensitivities from SEDAR 57 not explicitly analyzed during SEDAR 91 hold for SEDAR 91 because the underlying SS3 model framework is nearly identical.

The models assume a Beverton-Holt stock-recruitment relationship with a steepness values of 0.99 – this effectively decouples spawning stock biomass and recruitment and defaults to a “null” stock-recruitment relationship (Brooks, 2024). Assuming this null relationship, coupled with the inability to estimate annual recruitment deviations (Figure 9.14) from the TIP data, R0 becomes one of the most influential model parameters. R0 is highly sensitive to model initialization, i.e., estimates of initial F (Table 8.5). Higher and lower estimates of initial F have an inverse relationship with the magnitude of estimate R0, as evidenced by model estimates of initial SSB (Tables 8.2, 8.8), and sensitivities in which initial equilibrium catch is explored, and sexes combined (Figure 9.26). This illustrates both the general sensitivity to and importance of model initialization. Future sociological investigations, e.g., oral histories or semi-structured interviews, could benefit future stock assessment by seeking information on what proportion of fishing by PR fleets occurred in PR waters prior to 1985. This information could complement the efforts made during this assessment to reconstruct historical catch, and potentially avoid the need to make initial equilibrium assumptions during future assessments.

There are several additional avenues for future US Caribbean spiny lobster research worth considering. Continued collection of length composition data from the SEAMAP-C dive survey, and/or the HJR Reefscaping cooperative research focused on collecting information on juvenile or sub-adult lobster, will be important to provide the model information on smaller lobsters that are either not vulnerable to the gear of the fishery, or caught and discarded for being undersized. Those data will further inform selectivity parameter estimates, and potentially annual recruitment deviations if cohorts can be identified. Further investigation into age structure of Caribbean spiny lobster via gastric ossicle mills, such studies conducted by Hutchinson et al. (2024) and Medina Martinez (2024) provide a specific age-length key for spiny lobster should length-based statistical catch-at-age models continue to be the primary tool for assessing stock status. Given the generally discrete growth process of marine invertebrate, i.e., molting, should future analysts

wish to consider a size-based assessment, there are generalized and lobster-specific frameworks available. For example, the Alaska Fisheries Science Center developed A Generalized Size-Based Assessment Modeling Approach for Alaskan Crab Stocks (GMACS) that may be worth applying to spiny lobster should an index of relative abundance become available in the future. Multiple stock assessment methods for Northeast American lobster (*Homarus americanus*) are also currently in development, but require an index of relative abundance (Burton Shank, NEFSC, personal communication), and would similarly benefit from more information on smaller lobsters.

Other sources of uncertainty suggest that US Caribbean spiny lobster may also benefit from a management strategy evaluation (MSE) approach. MSE is warranted when uncertainty threatens the efficacy of the current management approach (Walter et al. 2023). The magnitude of non-commercial harvest in PR waters remains highly uncertain, and that harvest remaining stable over time is a fundamental assumption of the SEDAR 91 model. MSE would offer an appropriate means of testing this assumption, and a simulated non-commercial fleet and associated selectivity in the operating models could be informed by expert opinion. Additionally, should local ecological knowledge-based data streams such as an index of relative perceived abundance (Shaff et al. 2023) become available, MSE is an appropriate framework for testing their utility in future stock assessment. Furthermore, environmental drivers of lobster population dynamics and the effects of market dynamics on the fisheries were primary concerns identified during participatory modeling in PR (Karnauskas et al. 2024). The effects of environmental nonstationarity on the performance of management procedures can be tested using MSE, as can the effects of market dynamics on fishing (Damiano et al., *in prep*).

6. RESEARCH RECOMMENDATIONS

- Continue the SEAMAP-C and HJR Reefscaping data collection programs for collecting spiny lobster size composition data.
- Leverage sociological research to obtain information on the proportion of PR landings were caught in PR waters prior to 1985.
- Consider the use of management strategy evaluation to explore the uncertainty in non-commercial catches.

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8 TABLES

Table 8.1: Summary of models for SEDAR 91.

Stage	Code	Model description
Initial	<i>init</i>	Model fit to catch and length composition data updated through 2023; start year changed to 1985; all model parameters remain unchanged from SEDAR 57
Initial	<i>2initF</i>	Same as <i>init</i> , but an initial fishing mortality parameter is estimated for each fleet: dive and pot/trap, and equilibrium initial catches are set to the geometric mean of landings during 1985-1987 from each fleet
Initial	<i>seamapc</i>	Same as <i>2initF</i> but is fit to length composition data from the Puerto Rico SEAMAP-C dive survey. SEAMAP-C data are aggregated into a single year: 2022, and exponential logistic selectivity parameters are estimated for the SEAMAP-C “fleet.”
Initial	<i>hjr</i>	Same as <i>seamapc</i> , but is fit to length composition data from HJR Reefscaping. HJR data are aggregated into a single year: 2022, and exponential logistic selectivity parameters are estimated for the HJR “fleet.”
Base	<i>new_eq</i>	Same as <i>hjr</i> , but equilibrium initial catches for each fleet are set to the global minima obtained from the equilibrium initial catch likelihood profile
Sensitivity	<i>selex1</i>	Same as <i>new_eq</i> , but the exponential logistic function for the dive fishery is initialized with logistic selectivity pattern; only 1st limb parameter is allowed to estimate
Sensitivity	<i>selex2</i>	Same as <i>new_eq</i> , but the exponential logistic function for dive fishery is initialized with logistic selectivity pattern; all three parameters are allowed to estimate
Sensitivity	<i>steep</i>	Same as <i>new_eq</i> , but steepness is fixed to 0.8
Sensitivity	<i>combsex</i>	Same as <i>new_eq</i> , but female von Bertalanffy growth parameters and weight-length relationship parameters are set to male values to approximate a single male sex model
Sensitivity	<i>lw</i>	Same as the <i>new_eq</i> , but uses the length-weight parameters estimated for the entire US Caribbean region
Sensitivity	<i>eq_hi</i>	Same as <i>hjr</i> but equilibrium initial catches are set to the highest values obtained from the equilibrium initial catch likelihood profile
Sensitivity	<i>eq_lo</i>	Same as <i>hjr</i> but equilibrium initial catches are set to the lowest values obtained from the equilibrium initial catch likelihood profile
Sensitivity	<i>eq_cv_hi</i>	Same as <i>new_eq</i> but the equilibrium initial catch cv is set to 0.3

Table 8.2: Puerto Rico spiny lobster parameters, standard deviations (SD), and coefficient of variation (CV) by model scenario: *init*, *2initF*, *seamapc*, *hjr*, *new_eq*. CV is calculated as the SD divided by the parameter estimate.

Parameter	Scenario	Estimate	SD	CV	Gradient
Dive selectivity 1 st limb	<i>init</i>	0.18	0.01	0.06	-1.8e-6
	<i>2initF</i>	0.18	0.01	0.06	-8.9e-6
	<i>seamapc</i>	0.18	0.01	0.06	1.2e-6
	<i>hjr</i>	0.18	0.01	0.06	-2.8e-7
	<i>new_eq</i>	0.18	0.01	0.06	-2.0e-6
Dive selectivity asymptote	<i>init</i>	0.36	0.005	0.01	1.2e-6
	<i>2initF</i>	0.36	0.005	0.01	-2.7e-5
	<i>seamapc</i>	0.36	0.005	0.01	8.4e-6
	<i>hjr</i>	0.36	0.005	0.01	8.1e-7
	<i>new_eq</i>	0.36	0.005	0.01	-5.2e-7
Dive selectivity 2 nd limb	<i>init</i>	0.28	0.03	0.11	-4.9e-7
	<i>2initF</i>	0.28	0.03	0.11	9.7e-7
	<i>seamapc</i>	0.28	0.03	0.11	-2.9e-6
	<i>hjr</i>	0.28	0.03	0.11	-1.6e-7
	<i>new_eq</i>	0.28	0.03	0.11	6.2e-7
Pot/trap selectivity 1st limb	<i>init</i>	0.18	0.01	0.06	-4.2e-7
	<i>2initF</i>	0.18	0.01	0.06	-4.3e-6
	<i>seamapc</i>	0.18	0.01	0.06	5.3e-7
	<i>hjr</i>	0.18	0.01	0.06	1.3e-8
	<i>new_eq</i>	0.18	0.01	0.06	-1.0e-6
Pot/trap selectivity asymptote	<i>init</i>	0.36	0.005	0.01	-4.9e-6
	<i>2initF</i>	0.36	0.005	0.01	-8.0e-5
	<i>seamapc</i>	0.36	0.005	0.01	-3.6e-5
	<i>hjr</i>	0.36	0.005	0.01	6.9e-7
	<i>new_eq</i>	0.36	0.005	0.01	--6.7-6
	<i>init</i>	0.33	0.04	0.12	5.5e-8
	<i>2initF</i>	0.34	0.04	0.12	1.1e-5

Pot/trap selectivity 2 nd limb	<i>seamapc</i>	0.34	0.04	0.12	1.8e-6
	<i>hjr</i>	0.34	0.04	0.12	-4.6e-8
	<i>new_eq</i>	0.33	0.04	0.12	1.7e-6
SEAMAPC selectivity 1 st limb	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA
	<i>seamapc</i>	0.14	0.09	0.64	1.4e-5
	<i>hjr</i>	0.14	0.09	0.64	9.6e-8
	<i>new_eq</i>	0.14	0.09	0.64	-1.1e-5
SEAMAPC selectivity asymptote	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA
	<i>seamapc</i>	0.29	0.06	0.21	2.0e-5
	<i>hjr</i>	0.29	0.06	0.21	-2.8e-7
	<i>new_eq</i>	0.29	0.06	0.21	-1.4e-5
SEAMAPC selectivity 2 nd limb	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA
	<i>seamapc</i>	0.10	0.15	1.50	3.5e-6
	<i>hjr</i>	0.10	0.15	1.50	9.1e-8
	<i>new_eq</i>	0.09	0.15	1.70	-3.8e-7
HJR selectivity 1 st limb	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA
	<i>seamapc</i>	NA	NA	NA	NA
	<i>hjr</i>	0.27	0.15	0.55	-7.7e-8
	<i>new_eq</i>	0.27	0.15	0.55	2.3e-6
HJR selectivity asymptote	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA
	<i>seamapc</i>	NA	NA	NA	NA
	<i>hjr</i>	0.29	0.03	0.10	-9.1e-8
	<i>new_eq</i>	0.29	0.03	0.10	7.3e-6
	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	NA	NA	NA	NA

HJR selectivity 2 nd limb	<i>seamapc</i>	NA	NA	NA	NA
	<i>hjr</i>	0.08	0.08	1.0	-9.7e-8
	<i>new_eq</i>	0.08	0.08	1.0	-8.6e-7
Dive retention	<i>init</i>	1.66	0.2	0.12	6.1e-7
	<i>2initF</i>	1.60	0.2	0.13	-5.0e-6
	<i>seamapc</i>	1.60	0.2	0.13	-7.6e-8
	<i>hjr</i>	1.60	0.2	0.13	2.2e-8
	<i>new_eq</i>	1.61	0.2	0.12	-1.3e-5
Pot/trap retention	<i>init</i>	2.70	0.45	0.17	8.7e-9
	<i>2initF</i>	2.60	0.44	0.17	2.8e-6
	<i>seamapc</i>	2.60	0.44	0.17	8.5e-6
	<i>hjr</i>	2.60	0.44	0.17	1.5e-7
	<i>new_eq</i>	2.62	0.44	0.17	-4.0e-7
Dive initial F	<i>init</i>	0.73	0.15	0.21	1.5e-6
	<i>2initF</i>	0.12	0.02	0.17	9.9e-6
	<i>seamapc</i>	0.12	0.02	0.17	7.0e-6
	<i>hjr</i>	0.12	0.02	0.17	-4.1e-8
	<i>new_eq</i>	0.18	0.04	0.22	-7.5e-6
Pot/trap initial F	<i>init</i>	NA	NA	NA	NA
	<i>2initF</i>	0.22	0.04	0.18	4.0e-6
	<i>seamapc</i>	0.22	0.04	0.18	-7.5e-7
	<i>hjr</i>	0.22	0.04	0.18	-1.3e-7
	<i>new_eq</i>	0.34	0.08	0.24	3.1e-6
Unfished Recruitment (R0)	<i>init</i>	6.98	0.081	0.01	8.2e-6
	<i>2initF</i>	6.95	0.10	0.01	-5.5e-5
	<i>seamapc</i>	6.95	0.10	0.01	3.5e-6
	<i>hjr</i>	6.96	0.10	0.01	1.9e-6
	<i>new_eq</i>	6.94	0.10	0.01	-1.2e-6

Table 8.3: Puerto Rico spiny lobster correlations between estimated parameters for the *new_eq* (base) model in descending magnitude of correlation.

Scenario	Estimated Parameters		Correlation Coefficient
<i>new_eq</i>	HJR selectivity asymptote	HJR selectivity 1 st limb	-0.910
<i>new_eq</i>	SEAMAPC selectivity asymptote	SEAMAPC selectivity 1 st limb	-0.902
<i>new_eq</i>	HJR selectivity 2 nd limb	HJR selectivity 1 st limb	-0.777
<i>new_eq</i>	SEAMAPC selectivity 2 nd limb	SEAMAPC selectivity 1 st limb	-0.728
<i>new_eq</i>	Initial F pot/trap	Initial F dive	-0.723
<i>new_eq</i>	HJR selectivity 2 nd limb	HJR selectivity asymptote	0.689
<i>new_eq</i>	Initial F dive	Unfished Recruitment (R0)	-0.674
<i>new_eq</i>	Initial F pot/trap	Unfished Recruitment (R0)	-0.641
<i>new_eq</i>	SEAMAPC selectivity 2 nd limb	SEAMAPC selectivity asymptote	0.573
<i>new_eq</i>	Dive selectivity asymptote	Dive selectivity 1 st limb	-0.529
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Pot/trap selectivity asymptote	0.497
<i>new_eq</i>	Dive selectivity asymptote	Unfished Recruitment (R0)	-0.481
<i>new_eq</i>	Dive selectivity 2 nd limb	Dive selectivity 1 st limb	-0.474
<i>new_eq</i>	Dive selectivity 2 nd limb	Unfished Recruitment (R0)	0.401
<i>new_eq</i>	Dive selectivity 2 nd limb	Dive selectivity asymptote	0.383
<i>new_eq</i>	Dive selectivity asymptote	Dive initial F	0.368
<i>new_eq</i>	Pot/trap selectivity asymptote	Unfished Recruitment (R0)	-0.365
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Pot/trap selectivity 1 st limb	-0.364
<i>new_eq</i>	Pot/trap selectivity asymptote	Pot/trap selectivity 1 st limb	-0.361
<i>new_eq</i>	Dive selectivity asymptote	Pot/trap initial F	0.328
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Unfished Recruitment (R0)	0.320
<i>new_eq</i>	Pot/trap selectivity asymptote	Pot/trap initial F	0.304
<i>new_eq</i>	Dive selectivity 1 st limb	Unfished Recruitment (R0)	0.295
<i>new_eq</i>	Dive selectivity 2 nd limb	Pot/trap initial F	-0.271

<i>new_eq</i>	Pot/trap selectivity asymptote	Dive initial F	0.258
<i>new_eq</i>	Dive selectivity 2 nd limb	Dive initial F	-0.248
<i>new_eq</i>	Pot/trap retention	Pot/trap selectivity asymptote	0.242
<i>new_eq</i>	Dive retention	Dive selectivity asymptote	0.238
<i>new_eq</i>	Pot/trap selectivity 1 st limb	Unfished Recruitment (R0)	0.220
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Dive initial F	-0.220
<i>new_eq</i>	Dive selectivity 1 st limb	Pot/trap initial F	-0.186
<i>new_eq</i>	Pot/trap selectivity asymptote	Dive selectivity asymptote	0.185
<i>new_eq</i>	HJR selectivity 2 nd limb	Unfished Recruitment (R0)	0.163
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Pot/trap initial F	-0.161
<i>new_eq</i>	SEAMAPC selectivity 2 nd limb	Unfished Recruitment (R0)	0.152
<i>new_eq</i>	Pot/trap selectivity 1 st limb	Dive initial F	-0.149
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Dive selectivity 2 nd limb	0.140
<i>new_eq</i>	Pot/trap selectivity asymptote	Dive selectivity 2 nd limb	-0.127
<i>new_eq</i>	Pot/trap retention	Pot/trap selectivity 2 nd limb	0.127
<i>new_eq</i>	Pot/trap selectivity asymptote	Dive selectivity 1 st limb	-0.123
<i>new_eq</i>	Pot/trap selectivity 2 nd limb	Dive selectivity asymptote	-0.117
<i>new_eq</i>	Dive retention	Dive selectivity 2 nd limb	0.116
<i>new_eq</i>	Dive selectivity 1 st limb	Dive initial F	-0.116
<i>new_eq</i>	HJR selectivity 2 nd limb	Dive initial F	-0.110
<i>new_eq</i>	HJR selectivity 2 nd limb	Pot/trap initial F	-0.104
<i>new_eq</i>	SEAMAPC selectivity 2 nd limb	Dive initial F	-0.103
<i>new_eq</i>	Pot/trap selectivity 1 st limb	Dive selectivity asymptote	-0.098
<i>new_eq</i>	SEAMAPC selectivity 2 nd limb	Pot/trap initial F	-0.098
<i>new_eq</i>	Pot/trap selectivity 1 st limb	Dive selectivity 2 nd limb	0.096
<i>new_eq</i>	SEAMAPC selectivity asymptote	Unfished Recruitment (R0)	-0.091

Table 8.5: Puerto Rico spiny lobster parameters, standard deviations (SD), and coefficient of variation (CV) for dive initial F, pot/trap initial F, and R0 by sensitivity model scenario: *selex1*, *selex2*, *steep*, *eq_hi*, *eq_lo*, *eq_cv_hi*, *combsex*, and *lw*. CV is calculated as the SD divided by the parameter estimate. If values are too small to be rounded to the second decimal point, then they are rounded to the third decimal point.

Parameter	Scenario	Estimate	SD	CV	Gradient
Dive initial F	<i>selex1</i>	0.33	0.05	0.15	-3.8e-8
	<i>selex2</i>	0.18	0.04	0.22	-6.3e-7
	<i>steep</i>	0.15	0.03	0.2	-2.9e-6
	<i>combsex</i>	0.01	0.14	14.0	5.3e-5
	<i>lw</i>	0.18	0.04	0.22	-4.6e-7
	<i>eq_hi</i>	0.04	0.01	0.25	1.1e-5
	<i>eq_lo</i>	0.27	0.06	0.22	-3.4e-6
	<i>eq_cv_hi</i>	0.18	0.07	0.39	3.4e-7
Pot/trap initial F	<i>selex1</i>	0.61	0.11	0.18	-4.3e-8
	<i>selex2</i>	0.34	0.08	0.24	-6.8e-7
	<i>steep</i>	0.29	0.06	0.21	-2.2e-7
	<i>combsex</i>	0.01	0.26	26.0	-3.7e-5
	<i>lw</i>	0.34	0.08	0.24	-3.4e-7
	<i>eq_hi</i>	0.08	0.01	0.13	-1.8e-6
	<i>eq_lo</i>	0.48	0.11	0.23	-8.6e-6
	<i>eq_cv_hi</i>	0.34	0.12	0.35	-4.6e-7
Unfished Recruitment (R0)	<i>selex1</i>	6.58	0.002	<0.001	8.4e-6
	<i>selex2</i>	6.94	0.10	0.01	5.7e-6
	<i>steep</i>	7.05	0.07	0.01	-6.9e-6
	<i>combsex</i>	9.85	19.16	1.95	6.8e-8
	<i>lw</i>	6.91	0.10	0.01	-4.6e-7
	<i>eq_hi</i>	7.02	0.11	0.02	-5.1e-6
	<i>eq_lo</i>	7.14	0.12	0.02	-3.3e-8
	<i>eq_cv_hi</i>	6.94	0.10	0.01	-1.0e-5

Table 8.6: Puerto Rico spiny lobster fishing mortality rate and spawning stock biomass ratios relative to the rate and biomass of the stock associated with the MSY proxy (based on SPR 30%) for the *init*, *2initF*, *seamapc*, *hjr* and *new_eq*(base) models. The relative fishing mortality ratio is expressed as a three-year geometric mean of the annual fishing mortality rates for 2021-2023 divided by the fishing mortality rate associated with MSY SPR 30%. The relative stock biomass ratio is expressed as the 2023 spawning biomass divided by the spawning stock biomass at MSY SPR 30%.

Metric	Scenario	Value
F Current / F SPR 30%	<i>init</i>	1.16
	<i>2initF</i>	1.25
	<i>seamapc</i>	1.25
	<i>hjr</i>	1.23
	<i>new_eq</i>	1.26
SSB 2023 / SSB SPR 30%	<i>init</i>	1.0
	<i>2initF</i>	0.93
	<i>seamapc</i>	0.93
	<i>hjr</i>	0.94
	<i>new_eq</i>	0.92

Table 8.7: Puerto Rico spiny lobster derived quantities of the MSY proxy (based on SPR 30%) in metric tons for the initial model (*init*), *2initF*, *seamapc*, *hjr*, and base model (*new_eq*). CV is calculated as the SD divided by the parameter estimate.

Scenario	MSY Proxy	SD	CV
<i>init</i>	185.76	13.78	0.07
<i>2initF</i>	180.10	15.51	0.09
<i>seamapc</i>	180.47	15.64	0.09
<i>hjr</i>	181.64	16.02	0.09
<i>new_eq</i>	179.56	15.38	0.09

Table 8.8: Puerto Rico spiny lobster derived quantities for unfished and initial spawning stock biomass in metric tons (mt) along with standard deviations (SD) and coefficient of variation (CV) for the base model. CV is calculated as the SD divided by the parameter estimate.

Derived Quantity	Scenario	Estimate	SD	CV
SSB Unfished (mt)	<i>init</i>	3.79x10 ⁸	3.08x10 ⁷	0.08
SSB Initial (mt)	<i>init</i>	7.33x10 ⁷	2.58x10 ⁷	0.35
Ratio SSB Initial: Unfished	<i>init</i>	0.193	0.05	0.26
SSB Unfished (mt)	<i>2initF</i>	3.66x10 ⁸	3.5x10 ⁷	0.10
SSB Initial (mt)	<i>2initF</i>	1.61x10 ⁸	3.63x10 ⁷	0.23
Ratio SSB Initial: Unfished	<i>2initF</i>	0.44	0.06	0.14
SSB Unfished (mt)	<i>seamapc</i>	3.67x10 ⁸	3.53x10 ⁷	0.10
SSB Initial (mt)	<i>seamapc</i>	1.62x10 ⁸	3.66x10 ⁷	0.23
Ratio SSB Initial: Unfished	<i>seamapc</i>	0.44	0.06	0.14
SSB Unfished (mt)	<i>hjr</i>	3.69x10 ⁸	3.61x10 ⁷	0.10
SSB Initial (mt)	<i>hjr</i>	1.65x10 ⁸	3.73x10 ⁷	0.23

Ratio SSB Initial: Unfished	<i>hjr</i>	0.45	0.06	0.13
SSB Unfished (mt)	<i>new_eq</i>	3.45x10 ⁸	3.32x10 ⁷	0.10
SSB Initial (mt)	<i>new_eq</i>	1.05x10 ⁸	3.19x10 ⁷	0.30
Ratio SSB Initial: Unfished	<i>new_eq</i>	0.30	0.07	0.23

9 FIGURES

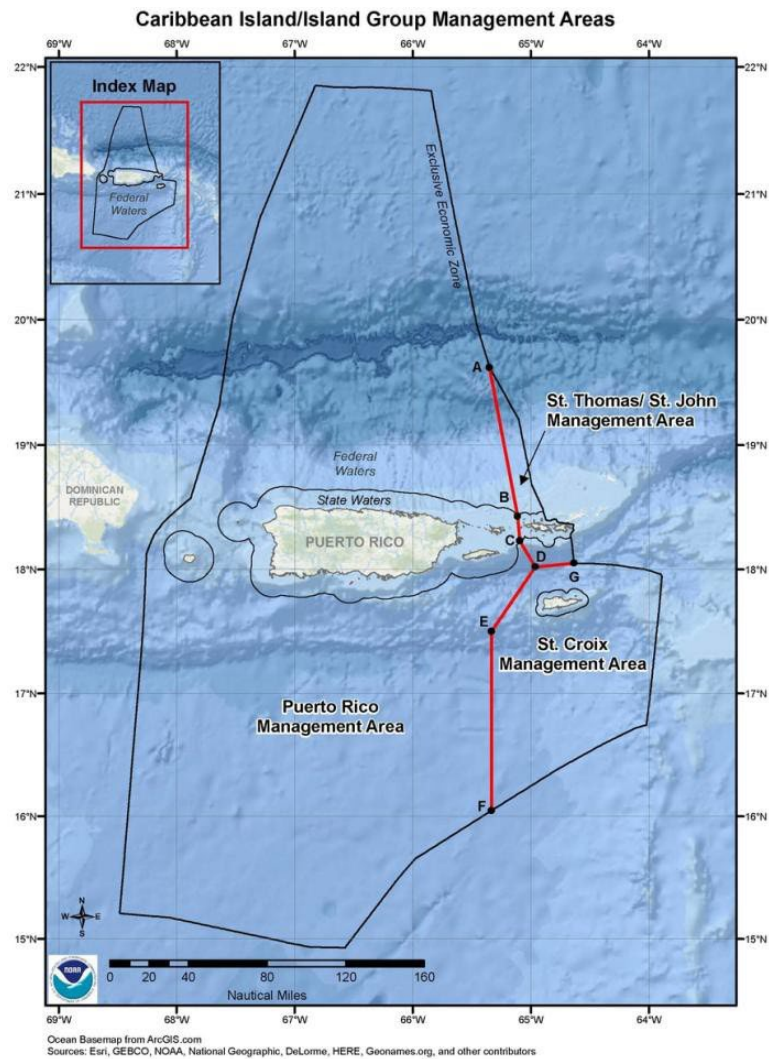


Figure 9.1: Jurisdictional boundaries of the Caribbean Fishery Management Council

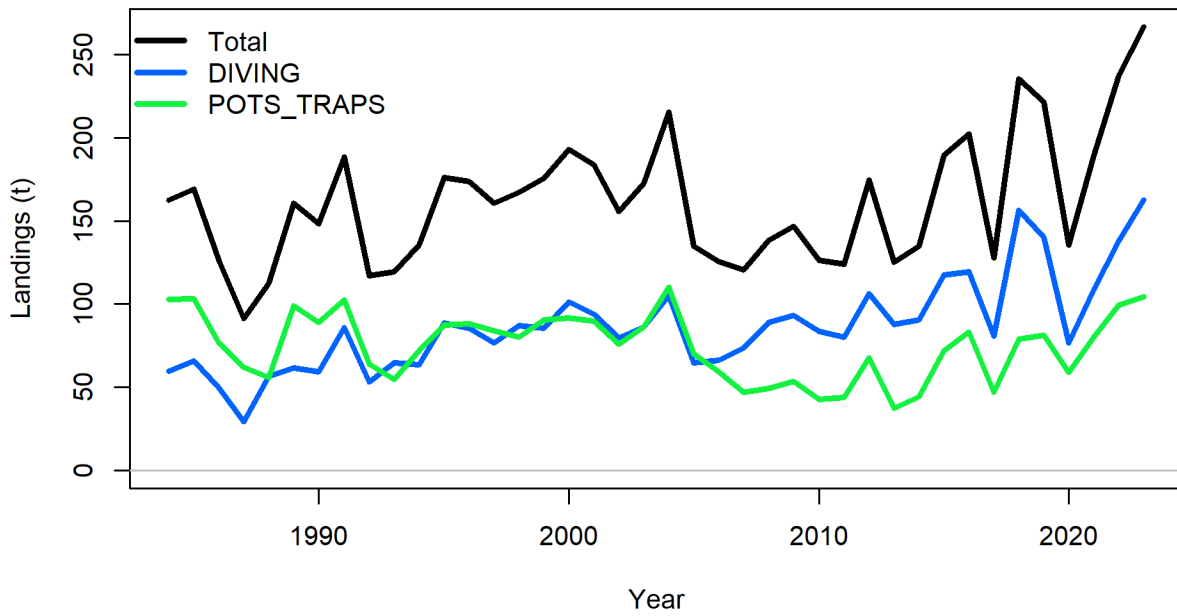


Figure 9.2: Puerto Rico spiny lobster landings (mt) during 1985-2023 by fleet: dive (blue), pot/trap (green), total (black).

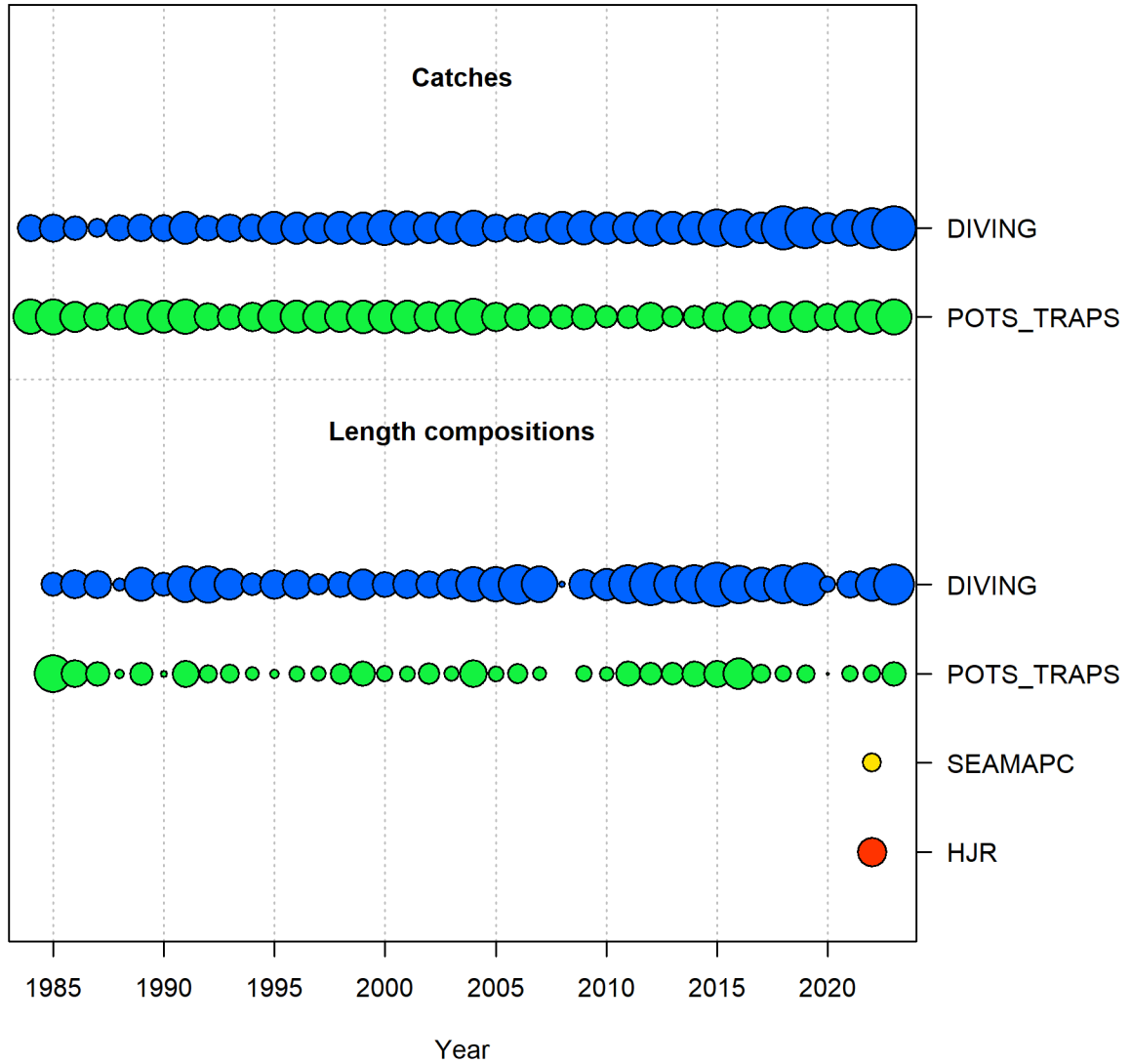


Figure 9.3: Puerto Rico spiny lobster catch (top) and length composition (bottom) data by fleet: dive (blue), pot/trap (green), SEAMAP-C (yellow), and HJR Reefscaping (red); circle size is indicative of the magnitude of catches (top) and sample sizes (effective sample size = the square root of the number of sampled trips) (bottom), respectively.

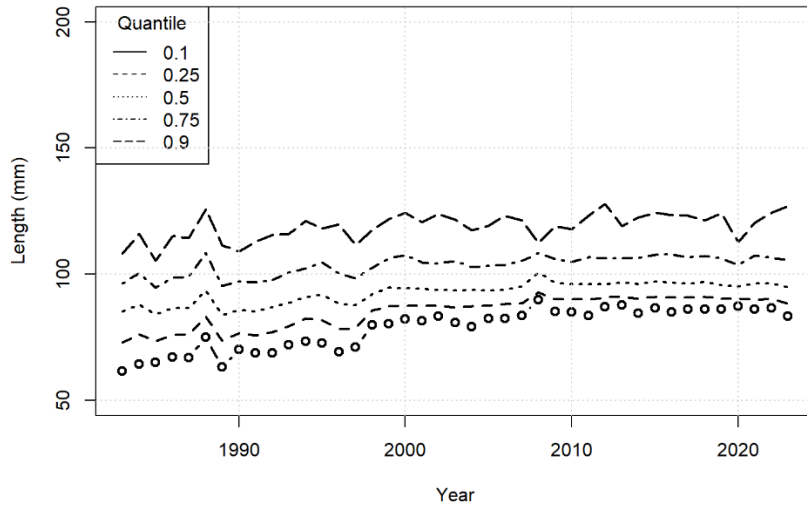


Figure 9.4: Median 10th, 25th, 50th, 75th, and 90th quantiles of length composition data (mm) for female Puerto Rico spiny lobster in the dive fishery during 1983-2023.

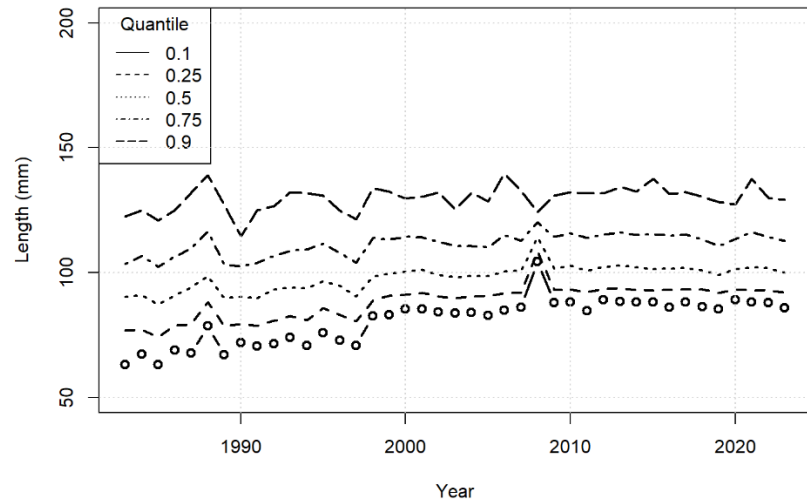


Figure 9.5: Median 10th, 25th, 50th, 75th, and 90th quantiles of length composition data (mm) for male Puerto Rico spiny lobster in the dive fishery during 1983-2023.

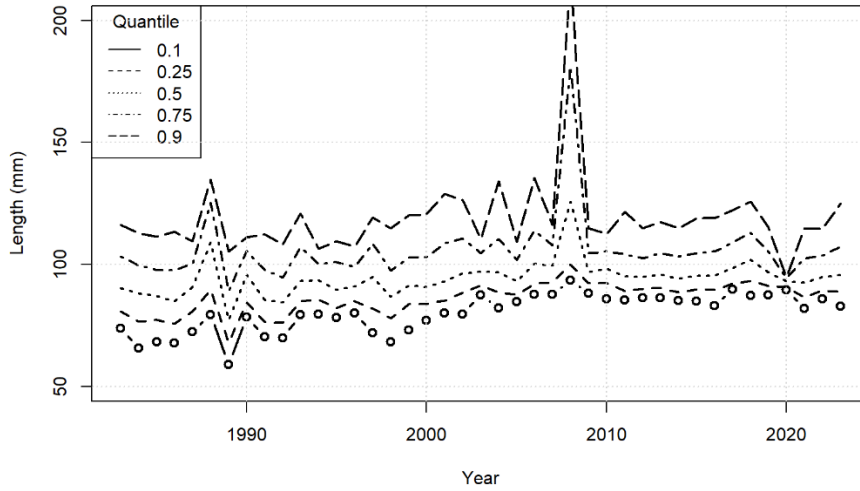


Figure 9.6: Median 10th, 25th, 50th, 75th, and 90th quantiles of length composition data (mm) for female Puerto Rico spiny lobster in the pot/trap fishery during 1983-2023. Data from 2008 were not included in model fitting.

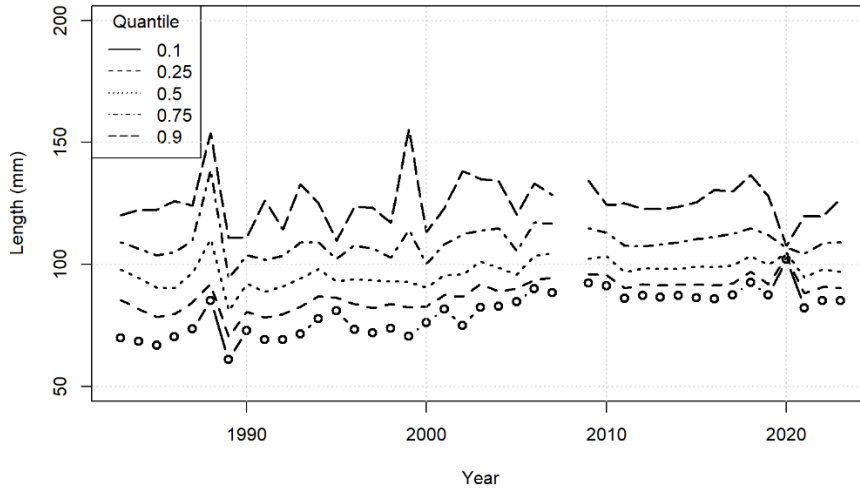
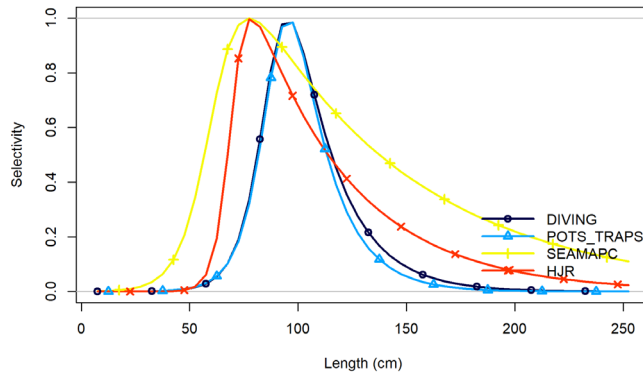
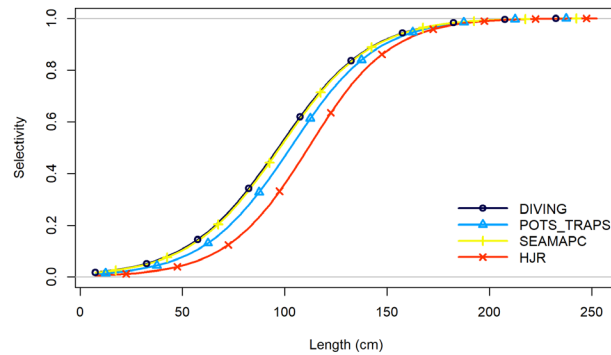


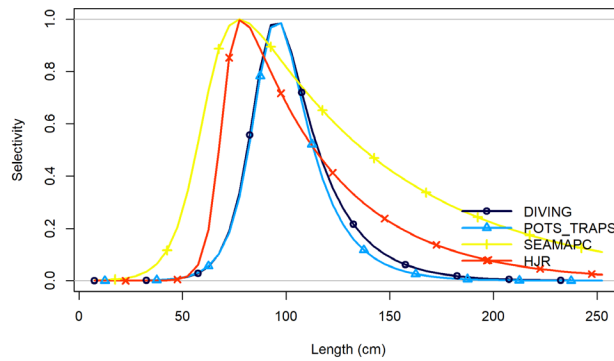
Figure 9.7: Median 10th, 25th, 50th, 75th, and 90th quantiles of length composition data (mm) for male Puerto Rico spiny lobster in the pot/trap fishery during 1983-2023. Data from 2008 were not included in model fitting.



(new_eq)



(selex1)



(selex2)

Figure 9.8: Puerto spiny lobster selectivity by model scenario: *new_eq* (top), *selex1* (middle), *selex2* (bottom), and by fleet: dive (dark blue), pot/trap (light blue), SEAMAP-C (yellow), and HJR Reefscaping (red).

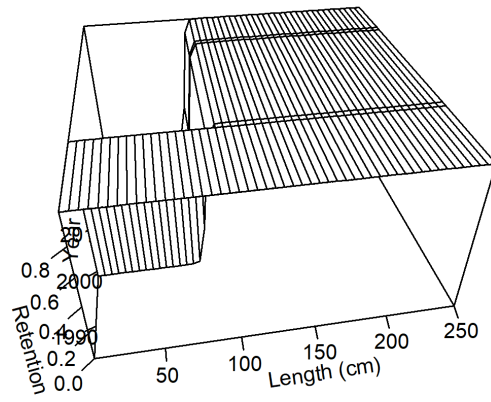
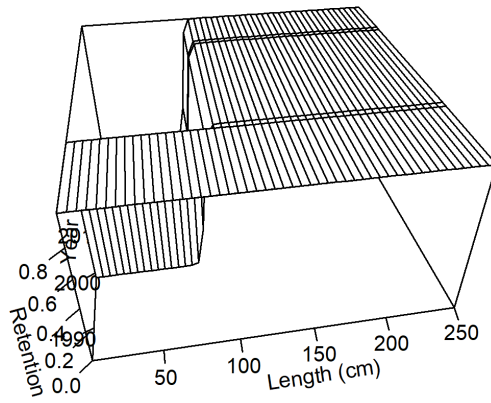


Figure 9.9: Time-varying retention curve surface for the first time-block (front) and second time-block (back) for female (top) and male (bottom) Puerto Rico spiny lobster in the dive fishery.

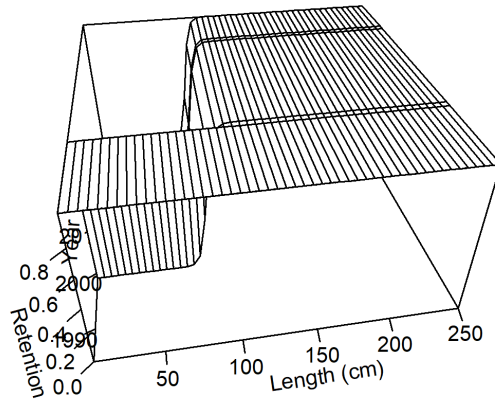
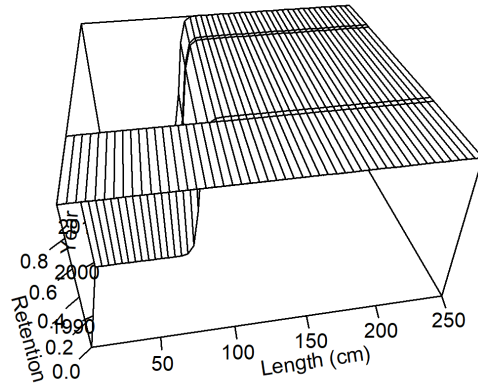


Figure 9.10: Time-varying retention curve surface for the first time-block (front) and second time-block (back) for female (top) and male (bottom) Puerto Rico spiny lobster in the pot/trap fishery.

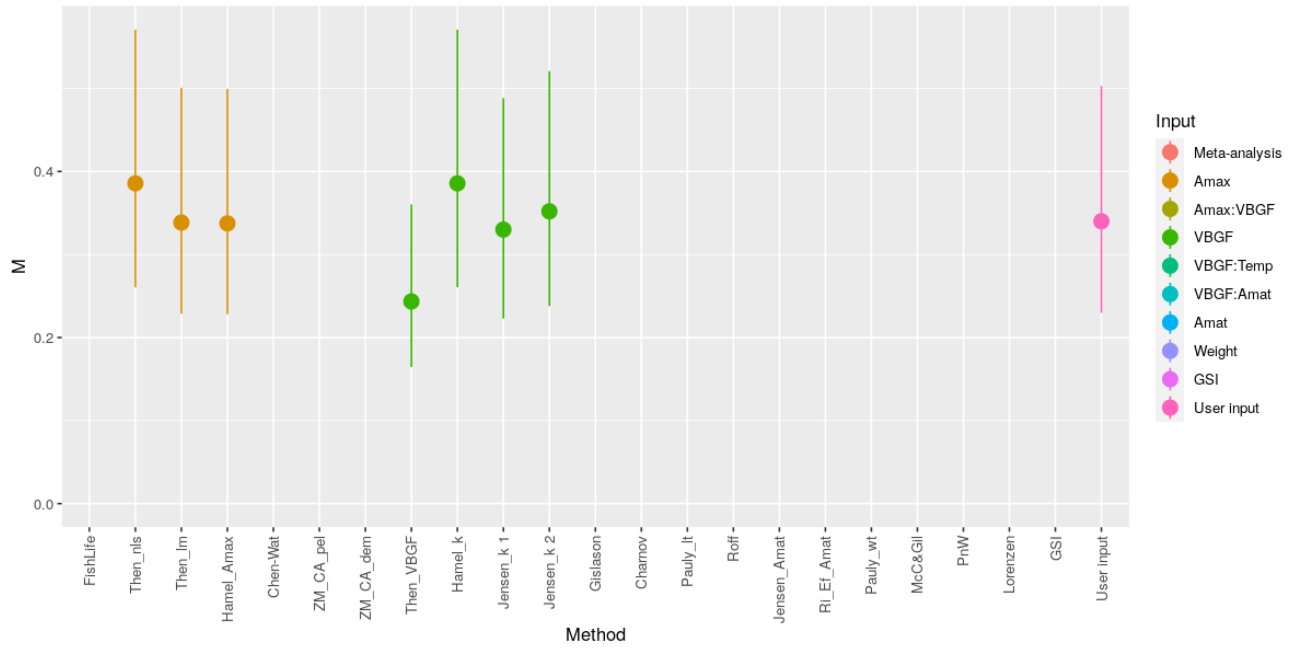


Figure. 9.11: Empirical estimates of natural mortality (M) based on maximum age and von Bertalanffy parameters for female Caribbean spiny lobster.

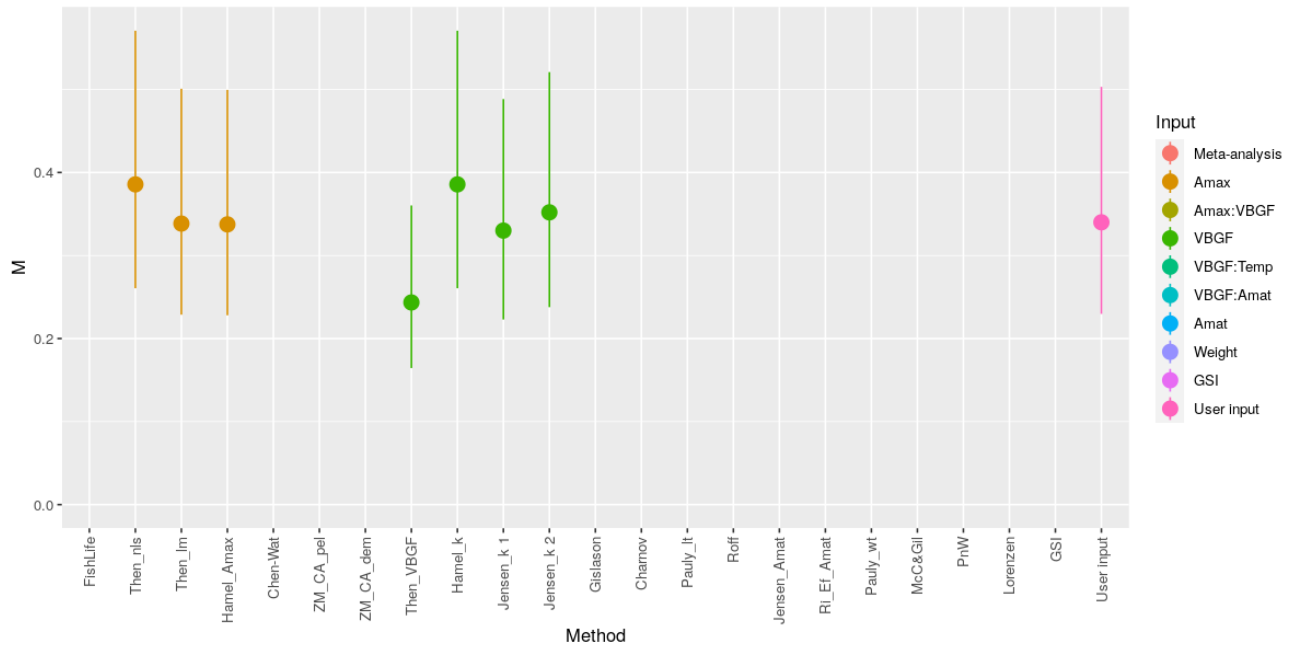


Figure 9.12: Empirical estimates of natural mortality (M) based on maximum age and von Bertalanffy parameters for male Caribbean spiny lobster.

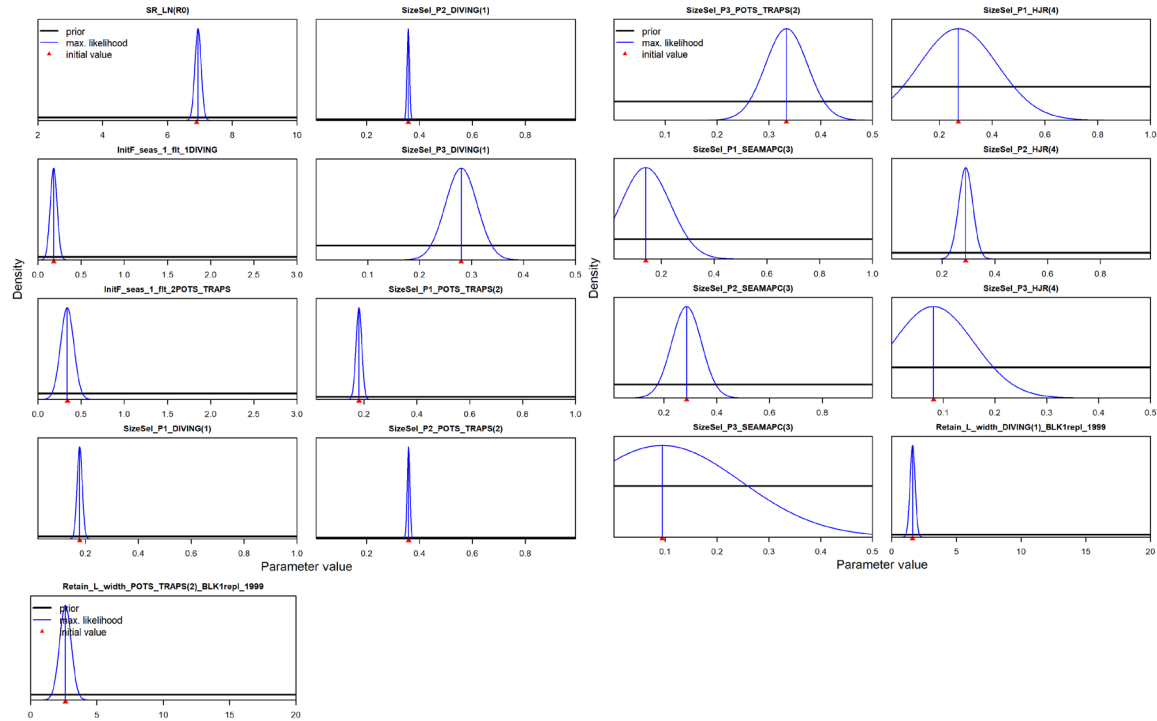
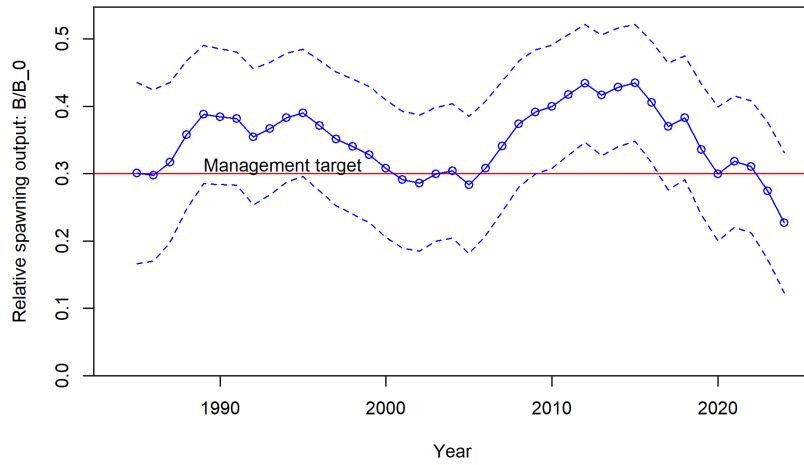
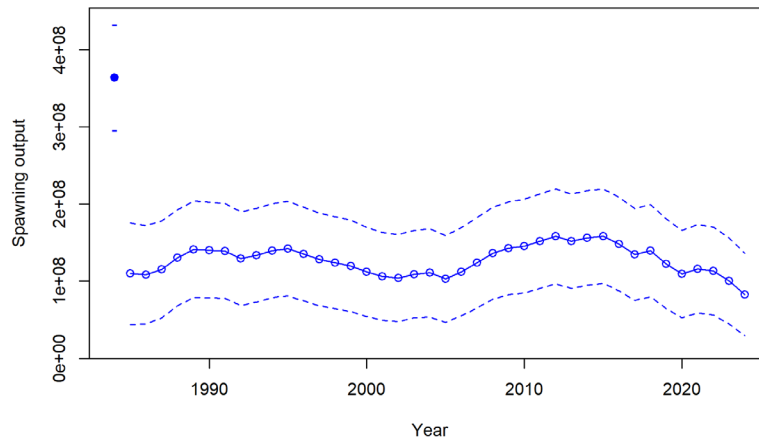


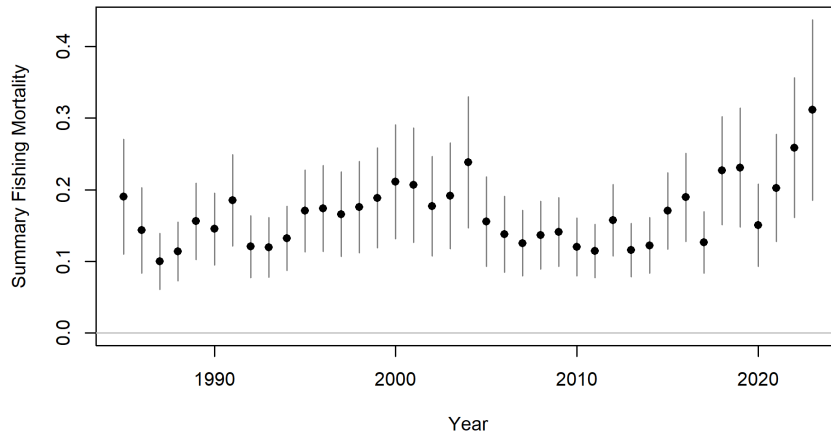
Figure 9.13: Puerto Rico spiny lobster parameter distribution for, in descending order from left to right, the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function, initial fishing mortality for the dive fishery, initial fishing mortality for the pot/trap fishery, the 1st limb parameter of the exponential logistic selectivity function for the dive fleet, the retention parameter for the pot/trap time-varying selectivity, the asymptote parameter of the exponential logistic selectivity function for the dive fleet, and the 2nd limb parameter of the exponential logistic selectivity function for the dive fleet, the 1st limb parameter of the exponential logistic selectivity function for the pot/trap fleet, the asymptote parameter of the exponential logistic selectivity function for the pot/trap fleet, and the 2nd limb parameter of the exponential logistic selectivity function for the pot/trap fleet, the 1st limb parameter of the exponential logistic selectivity function for the SEAMAP-C survey fleet, the asymptote parameter of the exponential logistic selectivity function for the SEAMAP-C survey fleet, and the 2nd limb parameter of the exponential logistic selectivity function for the SEAMAP-C survey fleet, the 1st limb parameter of the exponential logistic selectivity function for the HJR Reefscaping survey fleet, the asymptote parameter of the exponential logistic selectivity function for the HJR Reefscaping survey fleet, and the 2nd limb parameter of the exponential logistic selectivity function for the HJR Reefscaping survey fleet, and the retention parameter for the time-varying dive selectivity.



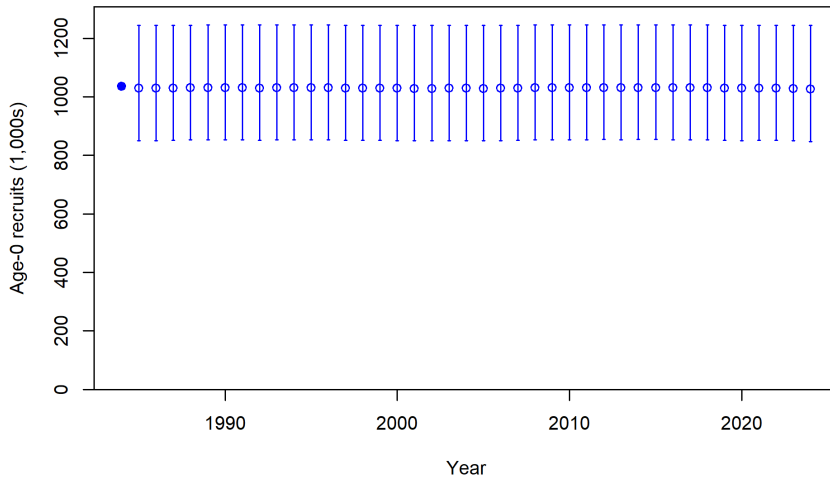
a. Spawning Biomass Ratio



b. Spawning Biomass



c. Fishing Mortality



d. Recruitment

Figure 9.14: St. Puerto Rico spiny lobster derived quantity time series from the base (*new_eq*) model. Derived quantities plotted over time for (a) the spawning biomass ratio (total biomass / unfished spawning stock biomass), (b) spawning stock biomass in metric tons, (c) fishing mortality (total biomass killed / total biomass), (d) and recruitment in thousands of fish. The shaded areas and vertical bars in the derived quantities time series represent 95% confidence intervals.

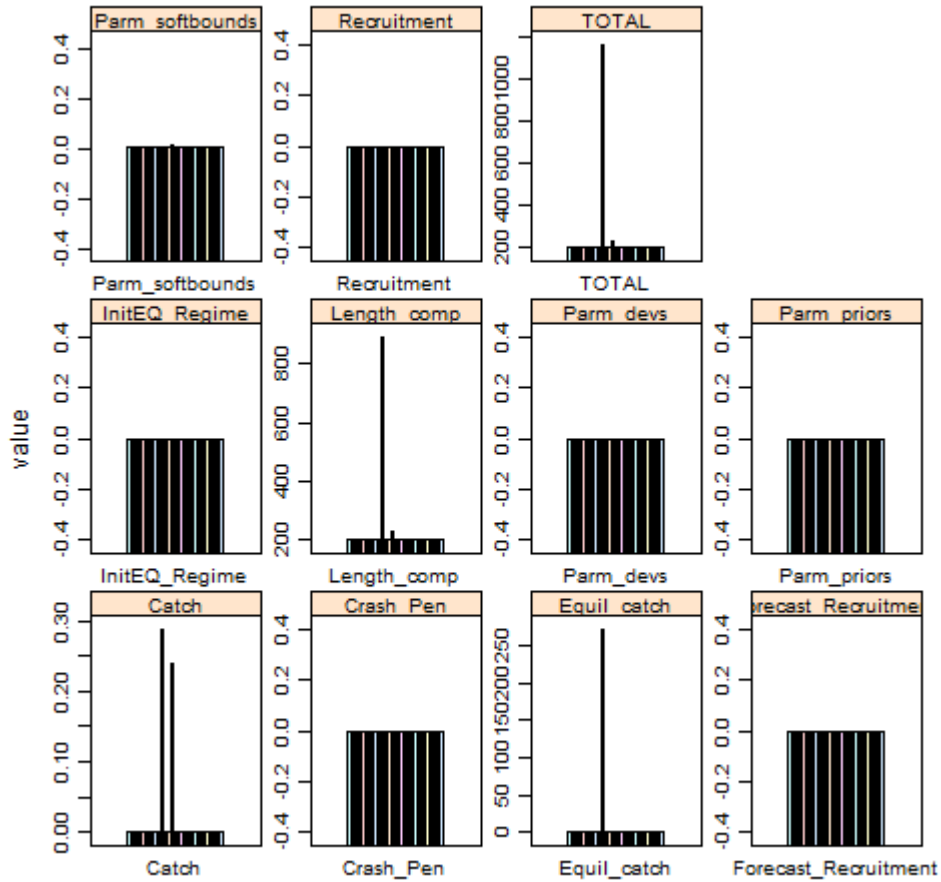


Figure 9.15: Puerto Rico spiny lobster jitter analysis total likelihood for the base (*new_eq*) model. Each panel gives the results of 40 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 50% from each model’s predicted values using a uniform distribution in cumulative normal space.

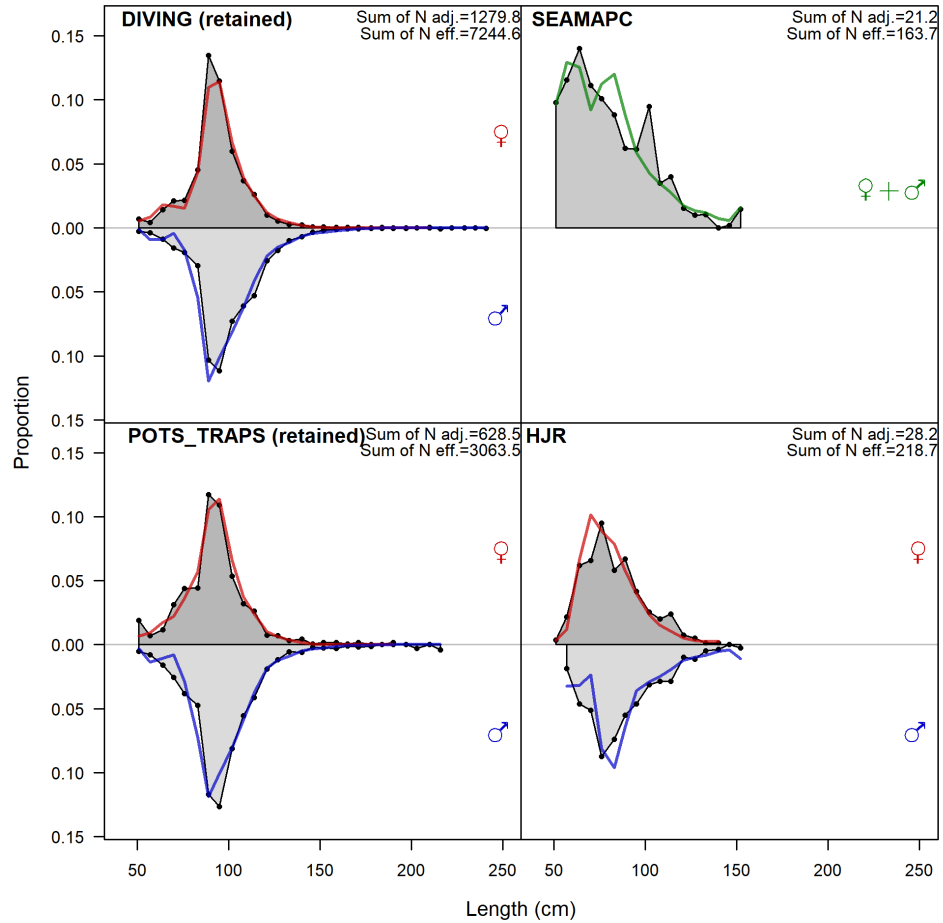


Figure 9.16: Puerto Rico spiny lobster observed and predicted length distributions (*new_eq*) in millimeters. Red and blue solid lines represent predicted length compositions, while gray regions represent observed length compositions. The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners. N adj and N eff are summed over sex.

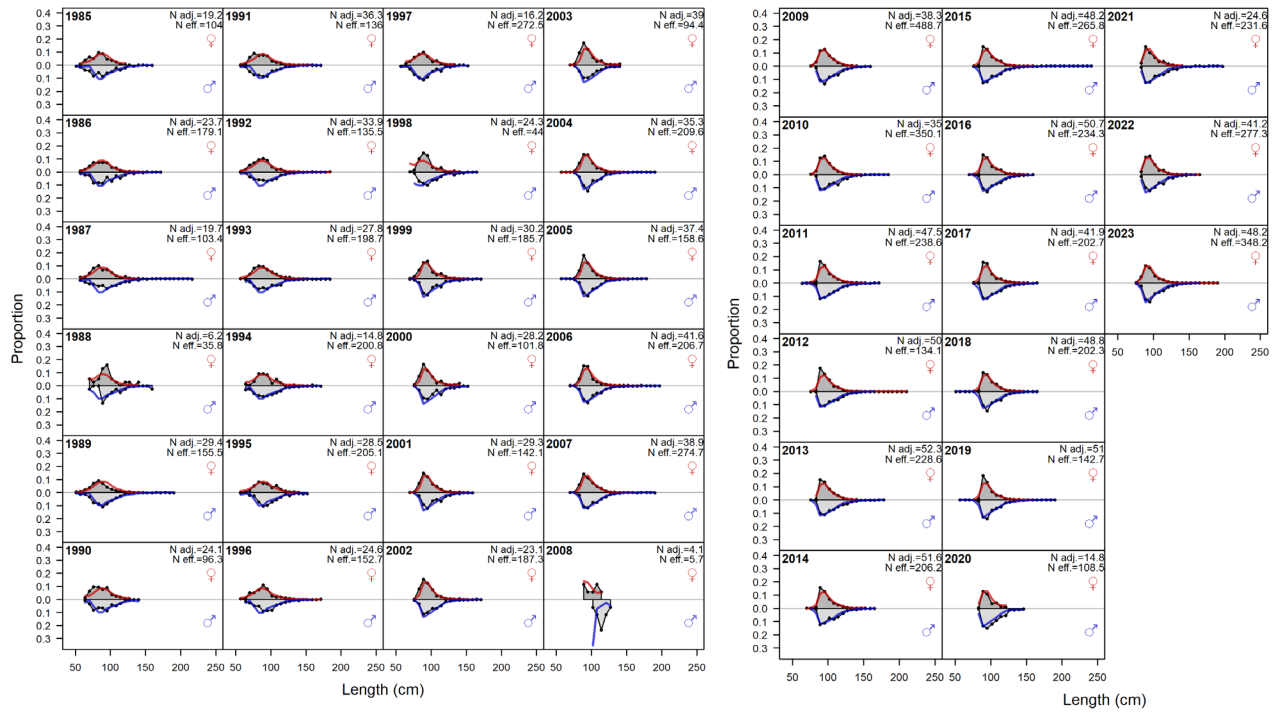


Figure 9.17: Puerto Rico spiny lobster observed (grey) and predicted (solid line) dive fleet length composition (*new_eq*) by individual year and sex: females (red) and males (blue). The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners. N adj and N eff are summed over sex.

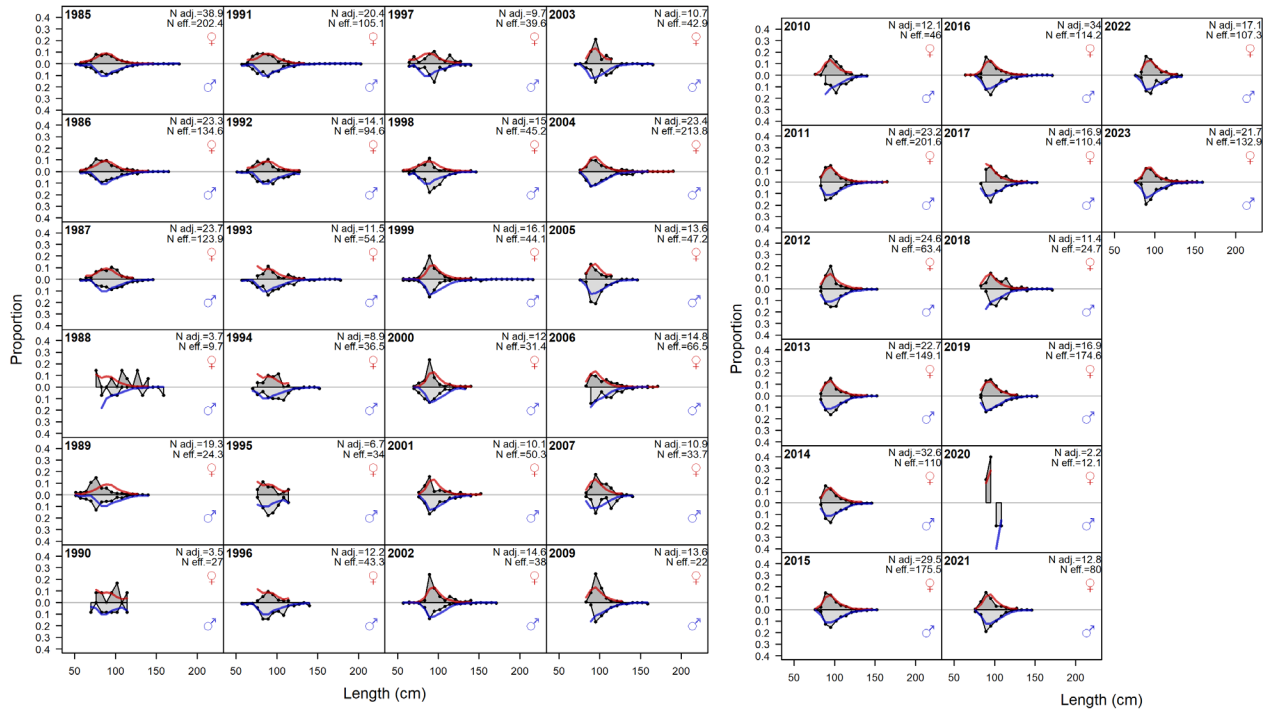


Figure 9.18: Puerto Rico spiny lobster observed (grey) and predicted (solid line) pot/trap fleet length composition (*new_eq*) by individual year and sex: females (red) and males (blue). The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners. N adj and N eff are summed over sex.

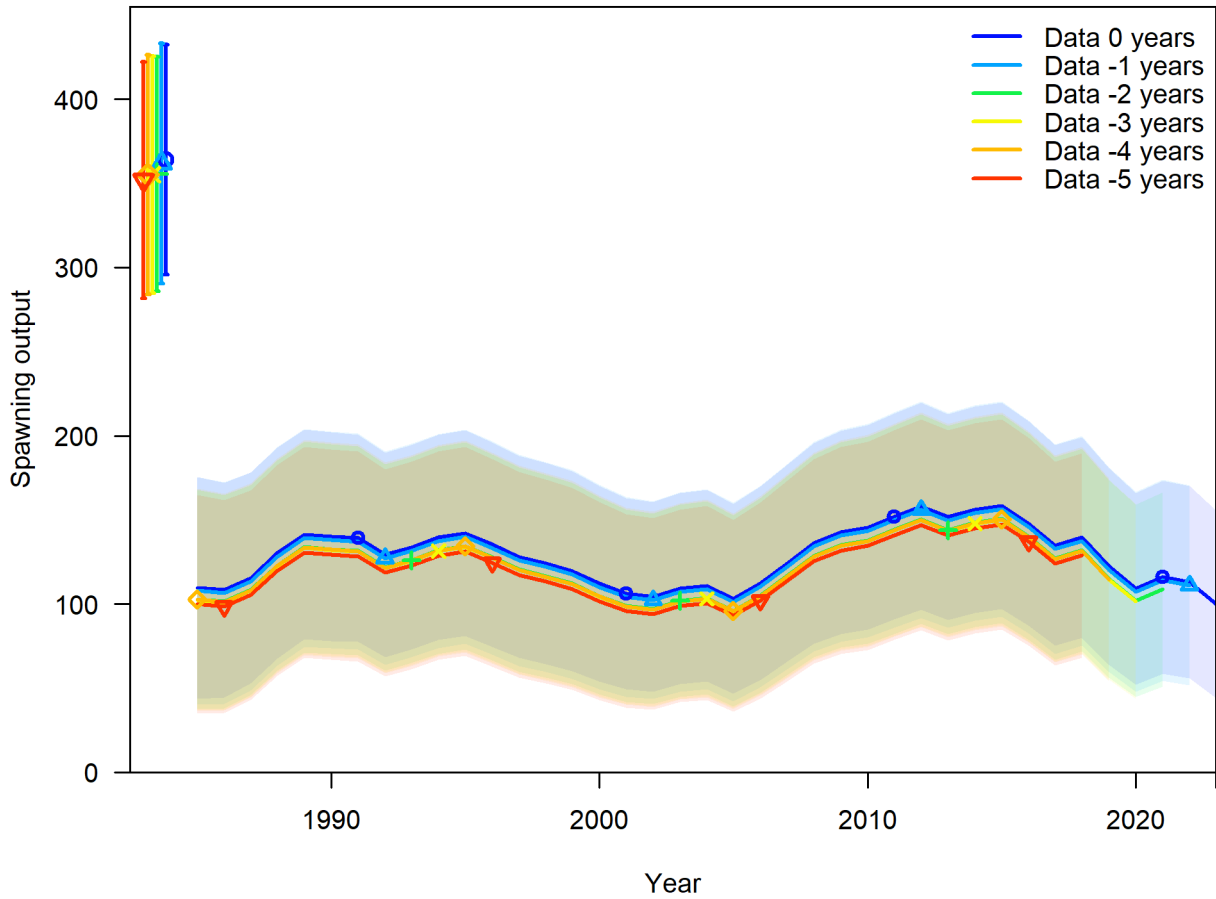


Figure 9.19: Puerto Rico spiny lobster retrospective analysis of spawning stock biomass (SSB) (*new_eq*) conducted by refitting models after removing five years of observation, one year at a time sequentially. Grey shaded areas are the 95% confidence intervals.

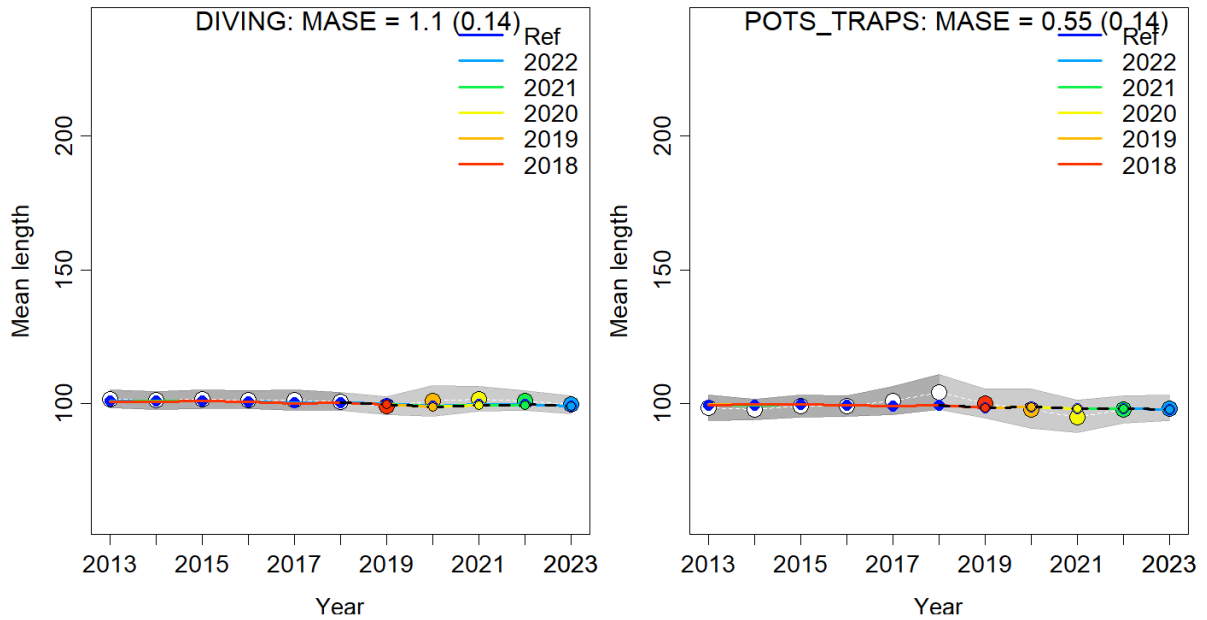


Figure 9.20: Puerto Rico spiny lobster hindcast cross-validation plots of mean absolute scaled error (MASE) from hindcast model prediction of length composition time series by fleet: dive fleet (left) and pot/trap fleet (right).

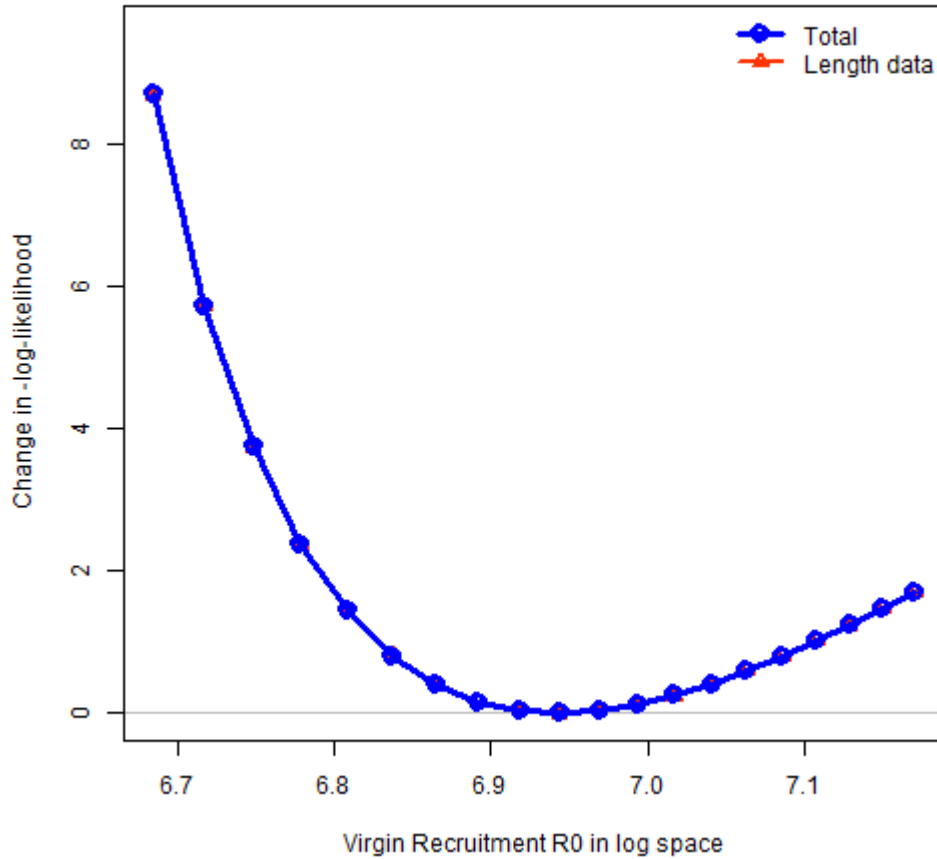


Figure 9.21: The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for Puerto Rico spiny lobster (*new_eq*). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed unfished recruitment values tested in the profile diagnostic run.

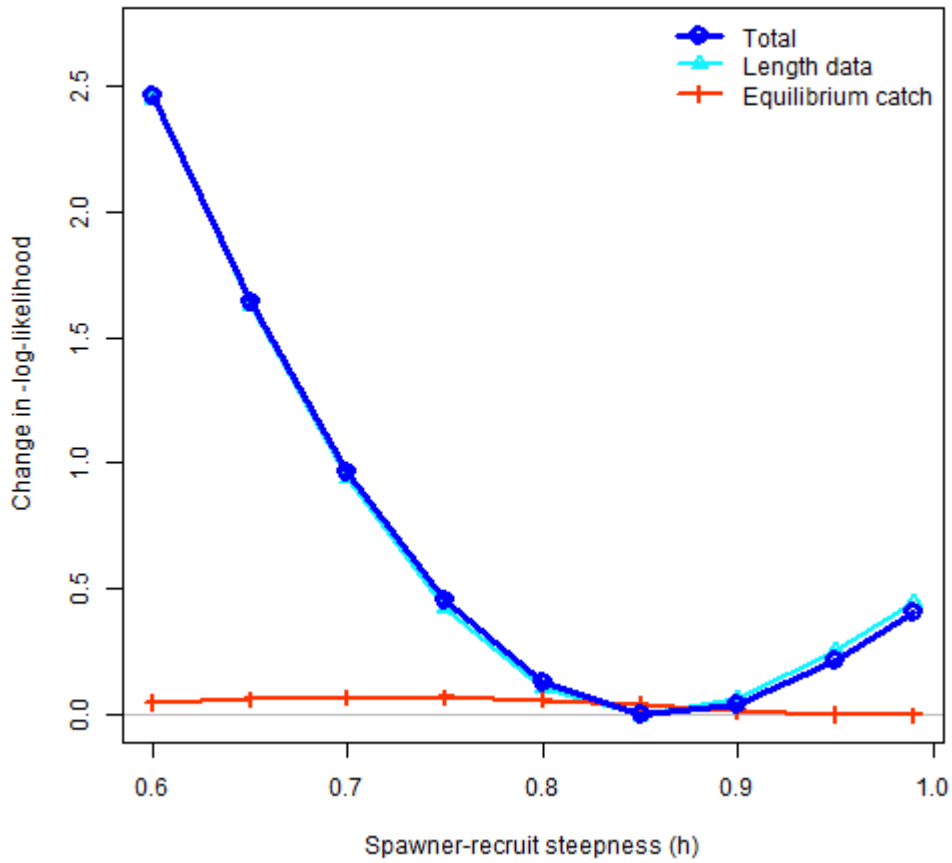


Figure 9.22: The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for Puerto Rico spiny lobster (*new_eq*). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.

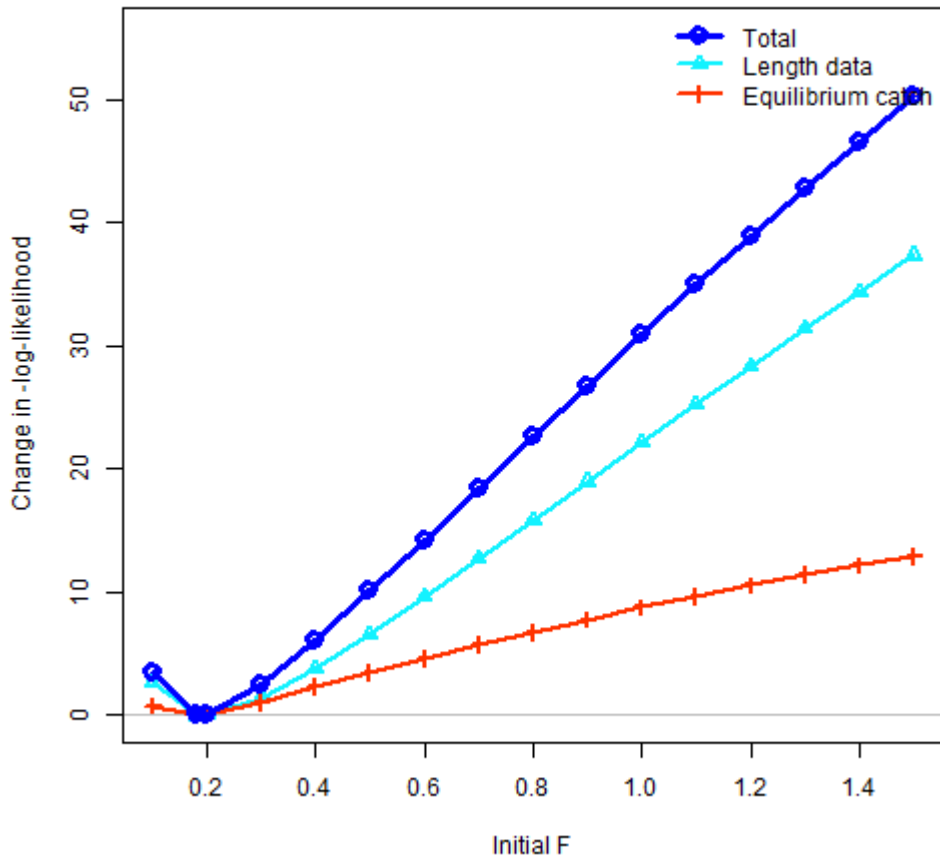


Figure 9.23: The profile likelihood for initial fishing mortality parameter for the Puerto Rico spiny lobster dive fleet (*new_eq*). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.

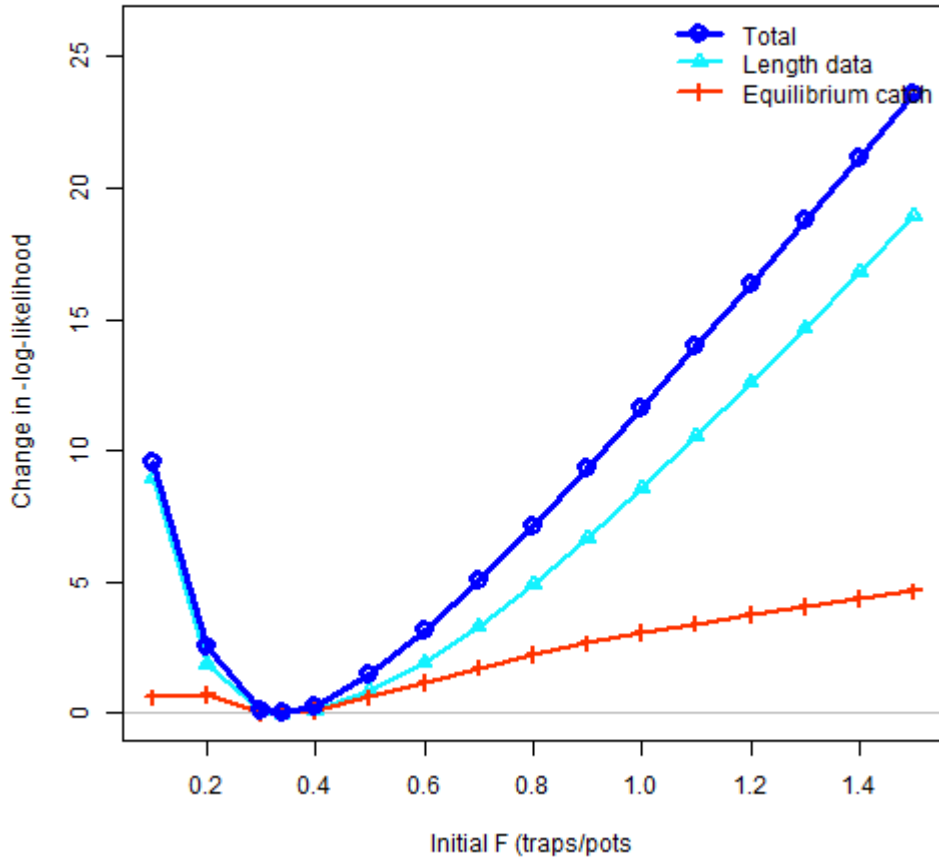
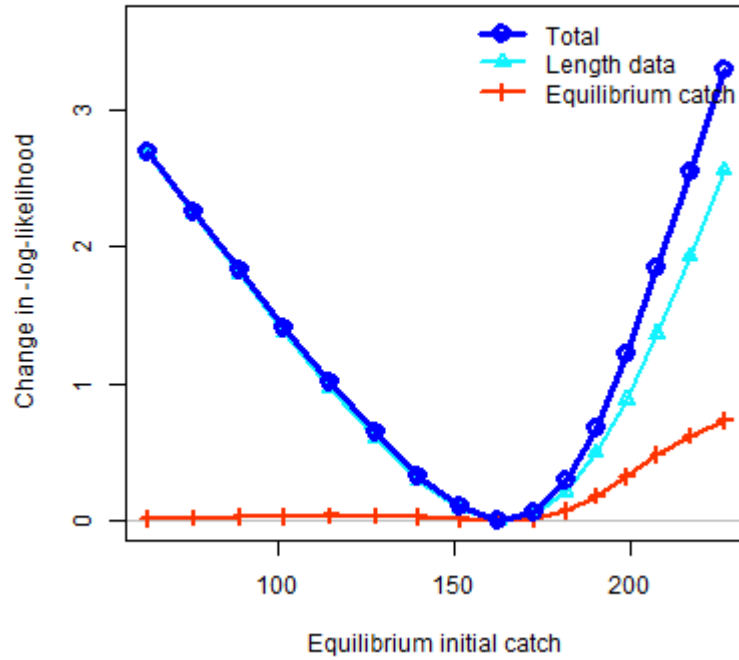
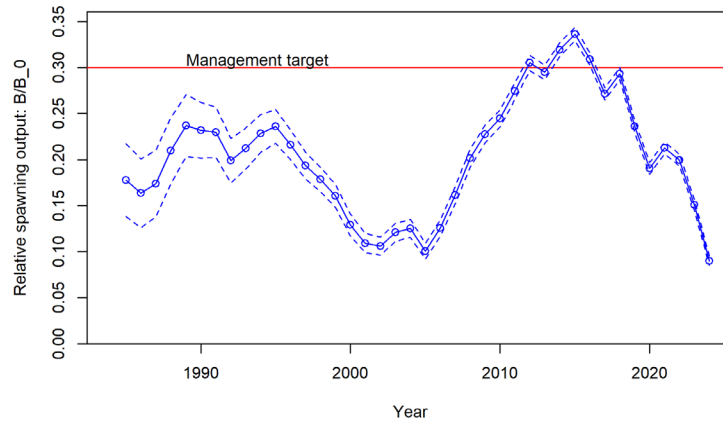


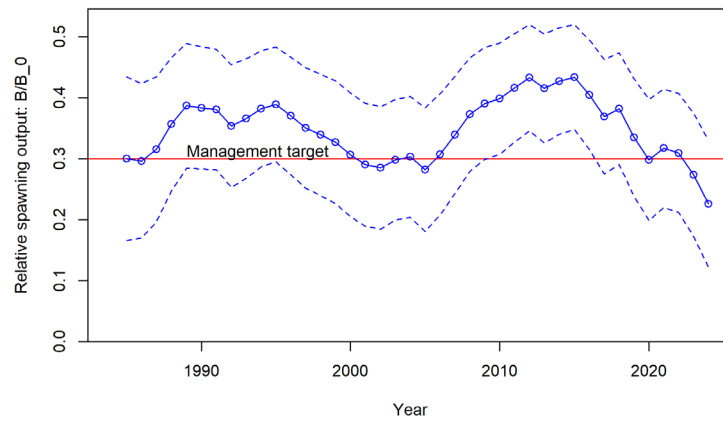
Figure 9.24: The profile likelihood for initial fishing mortality parameter for the Puerto Rico spiny lobster pot/trap fleet (*new_eq*). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.



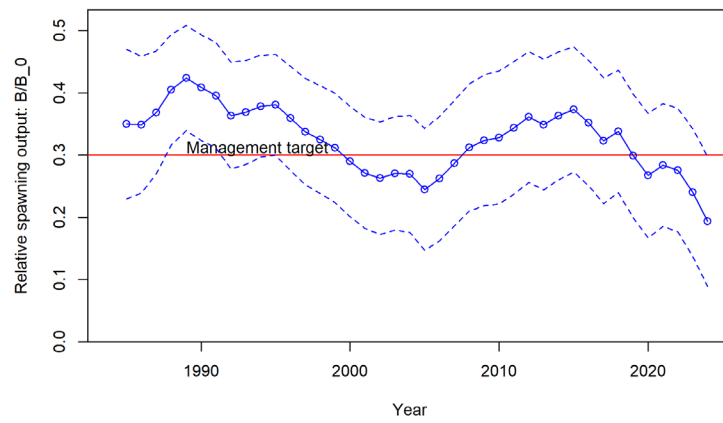
9.25: The profile likelihood for initial equilibrium catch for Puerto Rico spiny lobster (*new_eq*). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.



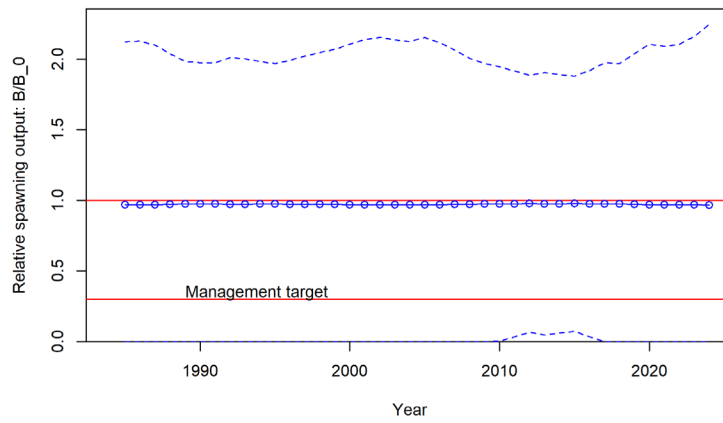
(selex1)



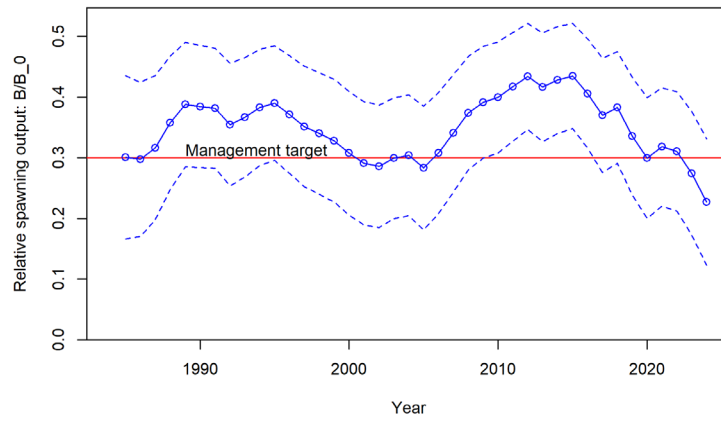
(selex2)



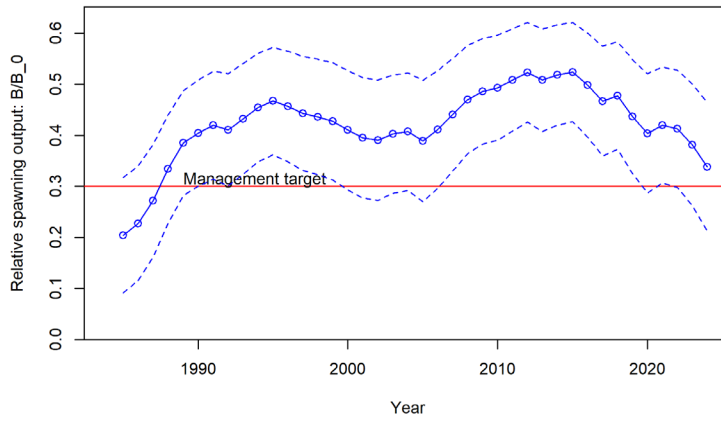
(steep)



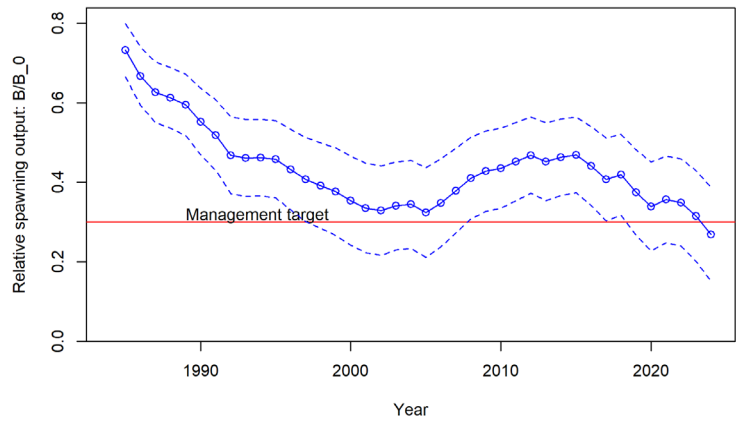
(combsex)



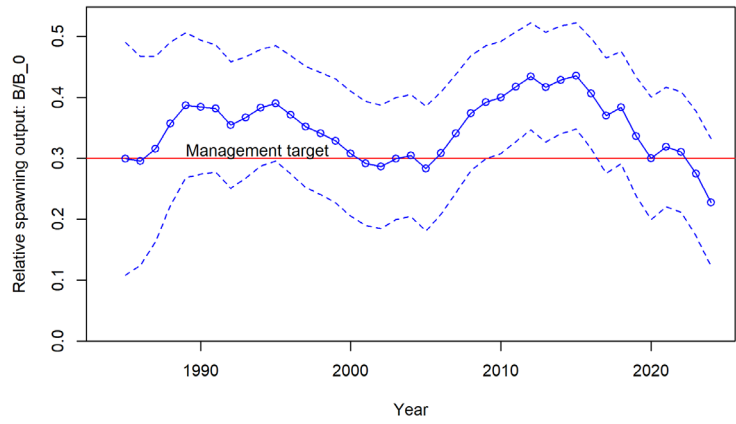
(lw)



(eq_hi)

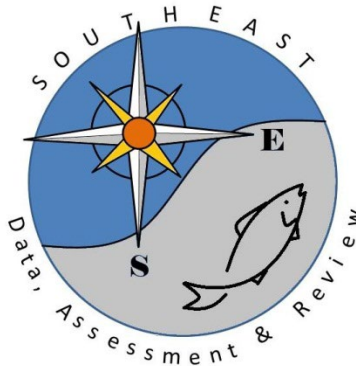


(eq_lo)



(eq_cv_hi)

Figure 9.26: Puerto Rico spiny lobster estimated relative spawning output (biomass/unfished biomass) from sensitivity models: *selex1*, *selex2*, *steep*, *combsex*, *lw*, *eq_hi*, *eq_low*, and *eq_cv_hi* in descending order.



SEDAR

Southeast Data, Assessment, and Review

SEDAR 91

US Caribbean Spiny Lobster – Puerto Rico

SECTION IV: Research Recommendations

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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- 3. REVIEW PANEL RESEARCH RECOMMENDATIONS..... 3**

1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

- When developing new research projects, consider how those projects can be designed to include data collection and/or analyses that would inform ecosystem models and analyses. The original objectives of the project should not be compromised, however.

1.1 LIFE HISTORY RESEARCH RECOMMENDATIONS

- Life history studies focused on the US Caribbean – generate region-specific parameters for growth, fecundity, natural mortality.
- Look for ongoing growth/aging work via SEAMAP-C and DNER who is involved in doing histology for reproductive analyses.
- Merge selectivity studies, life history data collection, and fishery-independent survey frameworks to determine how to get best data for stock assessment.

1.2 COMMERCIAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

1.2.1 Length Composition Research Recommendations

- Compare SEAMAP-C, HJR Reefscaping, and MER Consultants CL composition to TIP size composition.

1.2.2 Commercial Landings Research Recommendations

- - Track number of fishers/year in relation to annual landings- how does it vary?
- Support connectivity studies – consider spiny lobster as one stock vs. by island (metapopulation).
- Investigate weak/lack of correlation between TIP and landings data
- Demand analysis: look at price per pound (survey), market preferences, trends and correlation with landings, and for all islands.

- Investigate species associations with spiny lobster.
- Investigate recruitment connectivity between island platforms; e.g., STX seeding PR and other “hypotheses”.
- Increase funding for port samplers to improve TIP data collection in PR.
- Increase IT support for automated expansion factors calculation for the landings.

1.3 DISCARDS AND DISCARD MORTALITY RESEARCH RECOMMENDATIONS

- Discard information in the catch reports does not allow data on length or sex in current reporting schema.

1.4 RECREATIONAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

No research recommendations were provided.

1.5 MEASURES OF POPULATION ABUNDANCE RESEARCH RECOMMENDATIONS

- There were no recommendations from the panel regarding use of fishery-independent data in the Puerto Rico assessment model. However, the panel recommended that analysts not explore standardization of fishery-dependent data for use as an index of relative abundance.

2. ASSESSMENT PROCESS RESEARCH RECOMMENDATIONS

- Continue the SEAMAP-C and HJR Reefscaping data collection programs for collecting spiny lobster size composition data.
- Leverage sociological research to obtain information on the proportion of PR landings were caught in PR waters prior to 1985.
- Consider the use of management strategy evaluation to explore the uncertainty in non-commercial catches.

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

The Review Workshop was cancelled so there were not review panel research recommendations compiled.